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APPLIED MECHANICS REVIEWS

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BOUNDARY LAYERS IN THREE-DIMENSIONAL FLOW

W. R. SEARS

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FIFTY years have passed since Ludwig Prandtl presented his famous paper (1)[1] showing that, for fluids of small viscosity, viscous effects are essentially confined to a thin layer at the surface of a solid body, and giving the approximate equations that describe the flow in such a *boundary layer*. In this half century, boundary-layer theory has not only been the means of predicting such phenomena as skin friction and separation, vitally important to every fluid mechanicist, but has also provided the underlying rational basis for the study of real-fluid flows by ideal-fluid approximations, as in the whole realm of wing theory. It explains circulation, the critical Reynolds numbers of bluff bodies, and flow instabilities such as stalling and buffeting. It has been applied to unsteady flow and has been extended to subsonic and supersonic flows of compressible fluids. Recently it has successfully been used as the starting point of a process of successive approximations for flows of moderate, rather than large, Reynolds number (2).

The application of Prandtl's concepts to axisymmetric flows, as well as plane flows, was made relatively early and with equal success. This included flows with rotation or spin about the axis of symmetry (3), a type of problem that is still of considerable research interest (4–9).

More recently there has been much interest in three-dimensional problems without axial symmetry, and this is the category that we propose to review in the present note.

FLOWS WITH CYLINDRICAL SYMMETRY

The appearance of sweptback wings may have been responsible for this upsurge of interest in three-dimensional boundary layers; at any rate, the idea of studying the boundary layer on sweptback infinite cylinders occurred nearly simultaneously to four investigators in different parts of the world (10–13). Apparently it was Prandtl himself (10) who first noticed that his famous laminar-boundary-layer equations for incompressible flow

$$u_t + uu_x + vu_y + wu_z = -(1/\rho)p_x + \nu u_{zz} \qquad [1]$$

$$v_t + uv_x + vv_y + wv_z = -(1/\rho)p_y + \nu v_{zz} \qquad [2]$$

$$u_x + v_y + w_z = 0 \qquad [3]$$

are essentially simplified for such cases, provided that the coordinate axes (Fig. 1) are chosen so that the y-axis lies parallel to the axis of cylindrical symmetry. (Here u, v, w denote the components of velocity; x, y, z the locally orthogonal system of axes (Fig. 1); t the time; ρ the fluid density; and ν the kinematic viscosity μ/ρ. Subscripts denote partial differentiation.) For then all derivatives with respect to y must vanish, and Eqs. [1] and [3] become the equations of plane flow.

To be sure, this simplification would be illusory if the boundary conditions were not also independent of y, but this is also implied by the terminology "cylindrical flow"; i.e., the potential flow exterior to the boundary layer is also cylindrical in character. For the yawed infinite wing, for example, the potential flow is made up by superposition of a constant velocity component V, in the axial direction, upon the velocity field of plane flow about the normal cross section.

Thus the flow field $u(x, z, t)$, $w(x, z, t)$—the cross-flow field—is not affected by the yaw of the cylinder. Jones has called this the "independence principle."

Furthermore, in principle, the calculation of the entire three-dimensional flow pattern is a straightforward matter for any case where the plane flow problem has previously been solved. One needs only to calculate $v(x, z, t)$ from a linear differential equation with known variable coefficients (Eq. [2]). This has now been done in a number of interesting cases of steady flow and one rather academic case of unsteady flow (13–17). This subject has been reviewed in several places (16, 18), especially in the paper of Rott and Crabtree (19), where, in addition, a simple and practical procedure was presented for the estimation of boundary-layer characteristics in this type of problem, i.e., steady, incompressible, laminar flow over yawed cylinders. The subject will, therefore, not be reviewed again here.

The important extension to compressible flow, however, is less

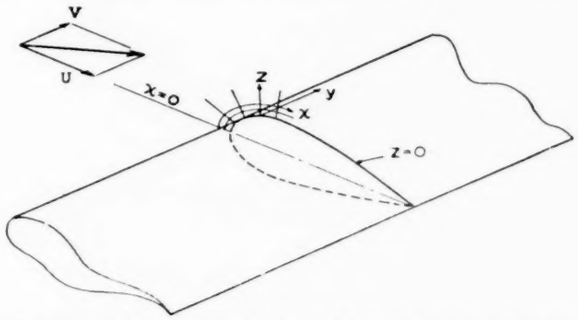

Fig. 1 Coordinate system for three-dimensional boundary-layer studies.

[1] Numbers in parentheses indicate References at end of paper.

well known; a first step in this direction was undertaken by Crabtree (20). It is clear that the independence principle no longer applies because the density ρ and viscosity μ, in the equations that replace Eqs. [1]–[3] shown, are dependent upon the resultant flow speed and not a component thereof. Confining his attention to cases of heat-insulated boundaries, Prandtl number equal to 1, and viscosity proportional to the temperature, Crabtree first applied the Illingworth-Stewartson transformation. This useful transformation reduces any plane compressible-flow problem, under the assumptions stated here, to a related incompressible-flow problem. In Crabtree's case it does this for the axial-flow equation—the equation for $v(x, z)$—putting it into the form of Eq. [2]. It leaves the equations for the cross-section flow pattern in a form resembling Eqs. [1] and [3] but involving an additional term; viz., the pressure-gradient term in Eq. [1] is multiplied by the factor

$$1 + \frac{\gamma - 1}{2} M_V^2 \left[1 - \left(\frac{v}{V} \right)^2 \right] \qquad [4]$$

where γ is the adiabatic exponent, V is the (constant) potential-flow component in the axial direction, and M_V denotes the Mach number of this component referred to the speed of sound at a stagnation point (line) of the cross flow, $a_0^2 - \frac{1}{2}(\gamma - 1)V^2$, where a_0 is the speed of sound at a true stagnation point.

The maximum value of the new term in expression [4] is, of course, $\frac{1}{2}(\gamma - 1)M_V^2$ or about $0.2M_V^2$ for air. Assuming that the component Mach number M_V is not greater than about 1 in practical cases, Crabtree suggests a successive-approximation procedure in which this term is neglected in the first step. This means *not* that the effect of compressibility is ignored in the first step, but that the only effect considered is that cared for by the Illingworth-Stewartson transformation. This extends the independence principle to compressible boundary-layer flow, in the first approximation.

As an example of this theory, Crabtree (20) considered the accelerated type of cross flow that becomes stagnation-point flow in the related incompressible case—i.e., after the Illingworth-Stewartson transformation. Thus, $U_{inc} = \text{constant} \times x_{inc}$. For this case he has not only calculated $v(x, z)$ in first approximation but has also taken the second step of the successive approximations; i.e., he has computed the effects of the correction term in [4] on the cross-flow boundary-layer velocities, taking $v(x, z)$ from the first approximation, and then the second approximation to $v(x, z)$. Fig. 2 is based on this work; it shows the cross-flow and axial-flow profiles at a certain chordwise station (x) where the cross-flow potential speed has increased (from zero at $x = 0$) to $0.488a_0$, a_0 being the speed of sound at stagnation. The axial component has the constant value $0.8a_0$. Both first- and second-approximation profiles are shown, together with the incompressible-flow profiles for comparison. It is seen that the effects of yaw on the cross-flow profile and boundary-layer thickness are appreciable, but that the subsequent effect on the axial component is small.

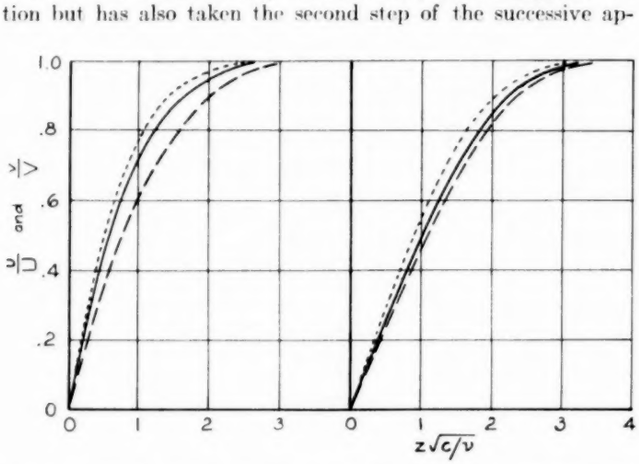

Fig. 2 Typical velocity profiles in the boundary layer of a yawed cylinder in compressible flow. Accelerated cross flow corresponding to stagnation-point flow ($U_{inc} = cx_{inc}$) in the related incompressible case. At this chordwise station $U/a_0 = 0.488$ and $V/a_0 = 0.8$, where a_0 is the speed of sound at stagnation. (*Left*) Profile of cross flow. (*Right*) Profile of axial flow. —— First approximation, neglecting effect of yaw on cross-flow boundary layer. — — Second approximation. - - - Incompressible profiles for comparison. ν denotes kinematic viscosity.

FLOWS WITH CONICAL SYMMETRY

The boundary-layer equations for conical flow seem to have been first discussed by Hayes (21) who pointed out that the boundary-layer flow must exhibit similar profiles along any ray and that the boundary-layer thickness must vary as $\sqrt{x}$ (x being the streamwise coordinate measured from the apex). The terminology "conical flow," of course, applies only to the potential flow and means that the fluid velocity components, pressure, density, and similar physical variables are constant along rays. Such flows occur at supersonic speeds around conical bodies and are of extreme importance in the design of supersonic missiles, aircraft, and wings. Independently, Moore (22) discussed the same problem and arrived at the same conclusions as Hayes. Later (23) he carried out calculations for circular cones at angles of attack. His results for relatively large angles of attack cast considerable light on phenomena of the three-dimensional boundary layer.

Because of the complexity of the equations for compressible boundary-layer flow over an inclined cone, Moore confined his attention to conditions in the plane of symmetry, at top and bottom. Let us assume that the angle of attack α is positive (nose up). Moore found that at small values of α he could calculate the boundary growth in the plane of symmetry without attention to the rest of the cone. At a certain value of α, however, the solution at the top became indeterminate. He showed that this is just the condition at which the boundary-layer flow over the whole circumference begins to affect that at the top. Below this angle the flow diverges at the top, as it does at $\alpha = 0$, due to the widening of the cone; at the critical α it just converges enough to make the boundary-layer flow in the plane of symmetry dependent upon the rest of the cone.

It may be surmised that this difficulty could be cleared up if the whole circumference were treated. At still a greater value of α, however, Moore encountered a different difficulty: nonexistence of any solution to the boundary-layer equations for the top of the cone. He demonstrated this nonexistence by studying the asymptotic behaviors of the equations. The Prandtl equations fail to describe the flow. This is undoubtedly a case of "component flow separation," such as was discussed by Jones (12) and occurs in many of the cylindrical-flow problems mentioned above (13, 14, 19). In Moore's problem it appears that the cross-flow (circumferential) boundary layer (which is, of course, an artificial concept, but often a useful one) has separated before reaching the top of the cone. The result is that a viscous region of large dimension has formed at the top of the cone, and the boundary-layer approximations have failed there.

NEARLY-TWO-DIMENSIONAL FLOWS. ROTATING BLADES

L. E. Fogarty (24) was probably the first to work out a case where the "three-dimensional terms" in the boundary-layer equa-

tions [1] and [3], although not equal to zero, are small and might be neglected in a first approximation. Actually, F. K. Moore, who at the time was studying the boundary layer of a sweptback wing at its plane of symmetry, suggested a study of nearly cylindrical wings, such as tapered wings, in 1949, and wrote down the boundary-layer equations for this interesting small-perturbation case. Later Hayes (21) called attention to this general class of problems, and recently Mager (25) has also considered them and worked out some examples.

The simplicity of these problems is evident from Eqs. [1]–[3]. Suppose that the boundary conditions are such that derivatives with respect to y can be expected to be small compared to those with respect to x. Then, to a first approximation, Eqs. [1] and [3] become once more the equations of plane flow, and Eq. [2] becomes a linear equation for $v(x, y, z, t)$ involving the plane-flow results.

The particular case considered by Fogarty is that of a cylinder of infinite span rotating steadily about an axis perpendicular to the axial direction, such as an idealized helicopter blade. To make this flow appear steady, one employs a rotating coordinate system fixed in the blade and must include some additional terms in Eqs. [1] and [2] due to the rotation. For large radial distances, as Fogarty showed, the extra terms in Eq. [1], as well as the terms vu_y in [1] and v_y in [3], are small. Specifically they are $O(c/y)$ or smaller, where c denotes the maximum extent of the blade in the x-direction (the blade chord) and y is the axial coordinate. Thus, to first order, these terms may be neglected and Eqs. [1] and [3] taken to be the same as for plane flow about the same blade profile. The equation for $v(x, y, z)$, retaining all terms of order c/y, is once again a linear equation involving plane-flow results. It is similar to the equation for the cylindrical component of yawed-cylindrical flow, but involves important centrifugal-force and pressure-gradient terms.

Once again the simplification would be illusory if the corresponding potential-flow field were not known. As a matter of fact, it was not known when Fogarty started his work, but the dilemma he faced inspired some study of potential flow about an infinite blade, and the result was found (26). It states that the cross flow at any y is just the plane potential flow about the blade profile at stream speed ωy, ω being the angular velocity of the blade, and it gives a remarkably simple formula for the cylindrical velocity component, which is independent of y! This result, apparently unknown before 1950, involves no approximation.

Fogarty solved two interesting problems, using his first-order theory. The first is the boundary layer on a rotating flat-plate blade. The cross flow in this case is just Blasius' flat-plate boundary layer; his results show the corresponding cylindrical (or radial) flow that is set up by the centrifuging action of the blade. His second problem involves the rotation of a certain round-nosed cylinder whose plane-flow potential velocity is given by $U = ax + bx^3$. It is interesting to note that very little outflow due to centrifuging appears in the results. In fact, the radial velocities are everywhere surprisingly small for this cylinder.

At present we do not know whether other cylindrical blades, perhaps those having higher suction peaks along their leading edges, will produce greater radial velocities, such as the engineer tends to expect on propeller and compressor blades. Fogarty wrote out the equations for the extension of the Pohlhausen-Wild procedure to this case, but they involved so many terms as to make numerical calculation impracticable. Currently, however, Miss M. E. Graham is working on an extension of Fogarty's problem of the simplified boundary-layer procedures mentioned above and applied to cylindrical flow by Rott and Crabtree. Her methods are based on the work of W. E. Smith (27), who worked out the Fogarty equations for a series of Falkner-Skan-Hartree profiles. Thus, just as Cooke's results (15) for these flows provided the basis for the Rott-Crabtree approximation, Smith's are making possible Miss Graham's work. It appears that the investigation is successful and that a practical procedure for routine estimate of blade boundary layers will be provided (28).

Fig. 3 shows an example of Miss Graham's results. The cylinder considered is a circular one, rotating about an axis through and normal to its centerline. Because of the large effects of boundary-layer separation on the potential flow for such a blunt shape, Miss Graham has used the cross-flow "potential" velocity

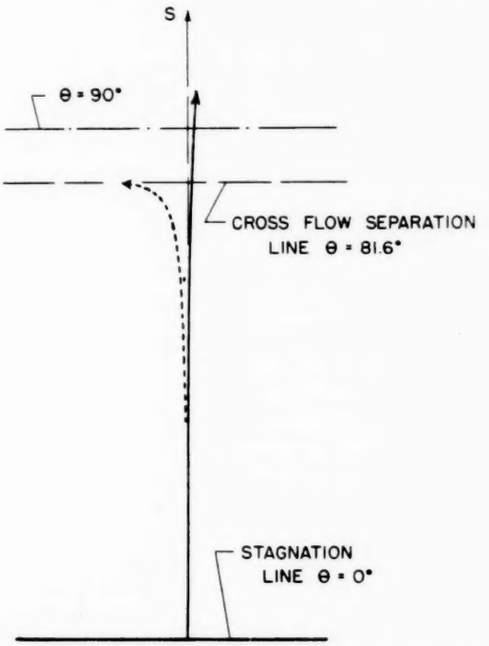

Fig. 3 Boundary-layer flow on a rotating circular cylinder. The streamline outside the boundary layer (solid) and the limiting streamline at the surface (dotted) are shown. The axis of rotation is at a distance of 5 diam toward the right and intersects the central axis of the cylinder. s denotes the circumferential distance measured around the cylinder from the stagnation line; θ is the corresponding angle.

distribution observed by Hiemenz (29); thus it is assumed that the Reynolds number at the radial station involved is near Hiemenz' value and that this distribution is not appreciably affected by rotation of the cylinder—as is exactly true for true potential flow. Also, the results of (26) have been used to estimate the axial component of "potential flow" from Hiemenz' cross flow. The "limiting streamline" drawn in Fig. 3 is the streamline just at the surface of the cylinder, along which, of course, the fluid flows with vanishing speed. The tendency of the fluid in the boundary layer to flow radially outward is clear, but its magnitude is surprisingly small.

Another kind of extension of Fogarty's work, namely to higher-order terms in c/y, i.e., to smaller distances from the axis of rotation, has been started by Tan (30). No results are yet available.

OTHER THREE-DIMENSIONAL FLOWS. "BOUNDARY REGIONS"

Few investigations have been made of three-dimensional boundary-layer flows outside the categories mentioned so far. One is Howarth's calculation (31) of the flow near a stagnation point of three-dimensional flow. Another important investigation is Moore's (22) on the boundary layers of flat plates of arbitrary planform. He showed that the Blasius solution holds for all such cases, for either incompressible flow or compressible flow with unit

Prandtl number and insulated plate. This is clearly the generalization of the analogous results for yawed infinite flat plates (12, 13), and states that the boundary-layer flow over a flat plate is always streamwise and is unaffected by the leading-edge contour.

The importance of Moore's investigation does not lie in just this result, which simply confirms one's intuitive expectations. Moore also pointed out that the result applies as well (according to the boundary-layer equations) to a plate with pointed leading edge, but for such a case it leads to a discontinuity in u_z along the streamwise coordinate x extending back from the point. Thus u_{zz} is infinite along such a line, in violation of one of the boundary-layer assumptions. In actual fact there must be a region near the line—Moore calls it a "wake"—wherein the boundary-layer equations are inapplicable.

N. H. Kemp (32) has suggested that such a region be called a "boundary region" in contrast to a "boundary layer." It is characterized by the fact that derivatives of velocity components in two directions, rather than one, are large e.g.,; of order $1/(\nu)^{1/2}$. Moore did not solve the problem of his boundary region but suggested that it would be of parabolic shape.

The same phenomenon occurs in other cases, such as the unsolved one of the quarter-infinite flat plate with one streamwise edge (32) and the related one of flow in a streamwise corner, such as is formed by two flat plates intersecting along a streamwise line. The latter problem has been solved by Carrier and Dowdell (33, 34) and also, approximately, by Loitsianskiĭ and Bolshakov (35). The writer is not aware of any other boundary-region solutions, except a number of studies (36–39) based on the linear Rayleigh equation or its equivalent. While these undoubtedly cast some light on the behavior of boundary-region flows, they do not, of course, constitute solutions of the actual problems.

Carrier's original treatment (33) of the corner problem is not correct—as has been pointed out by L. Howarth and by others (32)—because his solution does not satisfy all the conditions required in such a boundary region. Briefly, the situation is this: For a boundary region one has three equations of motion and the continuity equation

$$uu_x + vu_y + wu_z = -(1/\rho)p_x + \nu(u_{yy} + u_{zz}) \qquad [5]$$

$$uv_x + vv_y + wv_z = -(1/\rho)p_y + \nu(v_{yy} + v_{zz}) \qquad [6]$$

$$uw_x + vw_y + ww_z = -(1/\rho)p_z + \nu(w_{yy} + w_{zz}) \qquad [7]$$

$$u_x + v_y + w_z = 0 \qquad [8]$$

For the fluid of vanishing viscosity ($\nu \to 0$) that we consider in boundary-layer theory, the terms of Eqs. [5] and [8] remain $O(1)$, while the terms of [6] and [7] are all $O[(\nu)^{1/2}]$, in general. Nevertheless, these equations must be solved simultaneously with the other two. This is in contrast with the ordinary boundary-layer case, where only one of these equations involves small terms, and it reduces to a statement that the pressure gradient normal to the surface is small. Since it is small, it can be neglected and the pressure p becomes a known function, given by the potential flow.

In problems of Carrier's type, p can be eliminated only by cross differentiation between Eqs. [6] and [7], which yields an equation of third order. One is left with three simultaneous nonlinear equations for u, v, w; there is no "independence" of any components. Carrier's first solution failed to satisfy the third-order equation, but nevertheless furnishes a first approximation from which the correction terms have now been evaluated (34). The differences are indeed small.

The Loitsianskiĭ-Bolshakov treatment of the same problem is based on momentum-integral methods. It is interesting to notice that it begins with a certain assumption regarding the similitude of the interaction region at various streamwise locations, which, careful study reveals (and Carrier's analysis confirms), cannot be correct. Nevertheless, the results are undoubtedly approximately right and they do seem to agree fairly well with those of Carrier and Dowdell.

TURBULENT BOUNDARY LAYERS

It is an understatement to say that the progress reported here in the field of three-dimensional laminar boundary-layer flow has not been matched in the analogous problems involving turbulent boundary layers. Even for plane steady flow, the best methods of estimating turbulent boundary-layer growth and separation are empirical and are not considered satisfactory. Their extension to three dimensions is a doubtful matter, since, essentially, the relationships existing between the turbulent shearing stresses and the mean-flow variables are unknown.

This situation has been thoroughly reviewed by Rott and Crabtree (19). They have pointed out the availability of several interesting experimental investigations, some of which seem to imply an "independence principle" for yawed cylindrical flows with turbulent boundary layers. The existence of such a principle would cast important light on the mechanism of turbulent shear.

A recent investigation (39), however, fails to confirm any such principle for turbulent boundary-layer flow over yawed flat plates. It is found, on the contrary, that the boundary layer grows slightly more rapidly on a yawed plate than on an unyawed one, whereas the independence principle would predict a significantly slower growth on a yawed plate, at the same Reynolds number.

CONCLUSIONS

Extensions of Prandtl's laminar boundary-layer theory to three-dimensional cases without axial symmetry have met with considerable success. They have led to interesting new concepts such as independence principle, component separation, and boundary regions. Some cases of cylindrical and conical symmetry have been solved, as well as nearly-two-dimensional flows including boundary layers on rotating blades. One problem of a boundary region, namely, the flow in a corner, has also been worked out.

Analogous progress in problems involving three-dimensional turbulent boundary layers seems to await better understanding of the basic principles governing such layers in either two or three dimensions.

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Books Received for Review

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BRONWELL, A., Advanced mathematics in physics and engineering, New York, McGraw-Hill Book Co., Inc., 1953, xiv + 475 pp. $6.

CARATHÉODORY, C., Theory of function of a complex variable (translated by Steinhardt, F.), New York, Chelsea Publishing Co., 1954, xiv + 301 pp.

COMRIE, L. J., Chambers's shorter six-figure mathematical tables, New York, Chemical Publishing Co., Inc., 1954, xxvi + 387 pp. $6.50.

COOKE, R. G., Linear operators. Spectral and some other applications, London, Macmillan & Co.; New York, St. Martin's Press, 1954, xii + 454 pp. $10.

HAY, G. E., Vector and tensor analysis, New York, Dover Publications, Inc., 1953, 193 pp. $1.50.

KRAUS, R., Technische Mechanik, Bd. 1, Berlin, Verlag Technik, 1953, 336 pp., 210 figs.

LEVENS, A. S., Graphics in engineering and science, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, viii + 696 pp. $7.

MELAN, E., and PARKUS, H., Wärmespannungen infolge stationärer Temperaturfelder, Wien, Springer-Verlag, 1953, v + 114 pp., 30 figs. $4.40.

NILES, A. S., and NEWELL, J. S., Airplane structures. Vol. I, 4th ed., New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xvi + 607 pp. $7.75.

Riementriebe, Kettentriebe, Kupplungen (Schriftenreihe Antriebstechnik, Heft 12), VDMA Friedr. Vieweg & Sohn, Braunschweig, 1954, 262 pp. DM 24.50.

SACHS, G., Fundamentals of the working of metals, New York, Interscience Publishers, Inc.; London, Pergamon Press, Ltd., 1954, vii + 158 pp. $4.75.

SALVADORI, M. G., and SCHWARZ, R. J., Differential equations in engineering problems, New York, Prentice-Hall, Inc., 1954, xii + 432 pp. $6.50.

SCHÖNFELD, H., Regelungstechnik (Schriftenriehe des Verlages Technik, Bd. 92), Berlin, Verlag Technik, 1953, 84 pp., 39 figs. DM 7.20.

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STRECK, O., Grundlagen der Wasserwirtschaft und Gewässerkunde, Berlin, Springer-Verlag, 1953, x + 466 pp., 291 figs. DM 43.50.

WILLIAMS, C. D., and CUTTS, C. E., Structural design in reinforced concrete, New York, Ronald Press Co., 1954, 308 pp. $6.

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YARWOOD, T. M., Acoustics, London, Macmillan & Co., Ltd.; New York, St. Martin's Press, 1954, x + 346 pp. $3.50.

Letters to the Editor

2054. Concerning AMR 6, Rev. 2029 (June 1953): R. C. Baird and I. C. Bechtold, The dynamics of pulsative flow through sharp-edged restrictions with special reference to orifice-metering.

The first sentence of the fourth paragraph of this review, "Reviewer believes authors will find their two theories basically one and the same, namely, impedance," has essentially no meaning. In the first place, the authors were not attempting to present two theories. The paper had two objectives. Furthermore, it is not understood how "impedance" and "theories" can be considered identical.

It is also noted in the last sentence of the review that reference is made to "the differential equations involved." The paper contained no differential equations, nor is it recalled that it made any reference to differential equations.

I. C. Bechtold, USA

2055. Concerning AMR 6, Rev. 3520 (November 1953): C. F. Toms, Minimum comfortable cruising speed.

The reviewer's comments to this paper clearly reveal a difference in word usage. My definition of minimum of comfortable speed is qualitative only and is given in the third paragraph of the Note, and this should make it clear that the word "comfortable" is used by me to connote lack of difficulty, on the part of the pilot, in adhering to a flight plan. It may be that the reviewer takes the word "comfortable" to relate to a passenger's reaction to the short period motion of the airplane.

The minimum comfortable speed is not *defined* by me "as the speed . . . . is 5% of the forward speed." (I take it that the reviewer means "such that $dv_e/dv = 0.05$.") Toward the end of the Note it is said that "*if* the negative value . . . for reciprocating engines be taken as corresponding to $m = 1.05$, *then* . . . ." In other words, the Note seeks only to show what tendency there is for the value of the parameter m, which may be used to define the minimum comfortable speed, to vary as a result of a change in type of engine.

It may not be so widely known in the United States as in the United Kingdom that a turbine-engined airplane offers a wide choice of combinations of altitude, speed, specific range, and reserve rate-of-climb at a given airplane weight, or that to secure the best return for fuel burned, it is essential to increase altitude as the fuel level in the tank falls. To determine minimum comfortable speeds from the consideration of dynamic longitudinal stability characteristics (prior to flight testing) would involve a disproportionate amount of work, since many combinations of the variables already mentioned, and ambient temperature, would have to be considered; again, since the rate-of-climb of a turbine-engined airplane at the speed under consideration may be of the order of 200 fpm for a representative cruising technique, the effect of varying air density on the oscillatory motion would have to be allowed for.

What is hoped for is the production of experimental evidence which might provide a check on, or empirical corrections to, my deductions so that a simple working criterion for minimum comfortable speed differences due to differences in the type of power plant may be established. C. F. Toms, England

Theoretical and Experimental Methods

(See also Revs. 2072, 2075, 2076, 2079, 2084, 2091, 2101, 2114, 2140, 2141, 2283, 2291, 2296, 2344, 2354)

2056. Erdélyi, A., Magnus, W., Oberhettinger, F., and Tricomi, F. G., Tables of integral transforms. Vol. I (Bateman Manuscript Project), New York, McGraw-Hill Book Co., Inc., 1954, xx + 391 pp. $7.50.

Present volume is first of two which are companions and sequel to the three-volume set of Higher Transcendental Functions (HTF) by same authors. First two volumes of latter have appeared [see AMR **7**, Revs. 1365, 1366] and review for first volume describes history and aims of the Bateman Manuscript Project.

Bateman had planned to split the integral tables into several parts according to their field of application. Though such a plan entails considerable duplication to insure that each be a complete entity, it also has many advantages from the user's point of view. Editors have been able to restrict scope of Bateman's original plans. In recent years, several excellent tables of integrals of elementary functions have appeared, and it is assumed that present work will be used in conjunction with these. Thus work is concentrated on integrals involving the higher transcendental functions, though for the sake of completeness the tables also include integrals whose integrands are elementary functions. Viewed in this light, it is found that a large portion of the material could be organized in tables of integral transforms. Thus present volume and first half of volume to follow give integrals which can be so classified. Those which cannot be classified as integral transforms will appear in the second half of vol. II.

Vol. I contains extensive and modern lists of Mellin transforms and their inversions. It is known that some integrals may fall under all the above classifications. To cope with this difficulty, many of these are repeated so that each table is virtually complete within itself. Each table is subdivided according to the nature of the integrand (e.g., algebraic functions, logarithmic functions, Bessel functions, etc.). These are all listed in the contents to facilitate location of integrals of interest. Notation follows that in HTF. For convenience of the user, an appendix lists notations and needed definitions which appear in HTF. An index of notation is also provided.

The first three chapters give Fourier cosine, sine, and exponential transforms, respectively (464, 440, and 59 entries, respectively). Chapter four (824 entries) is a table of Laplace transforms, while the fifth chapter (705 entries) tabulates the inverse Laplace transform. Finally, chapters six (259 entries) and seven (194 entries) tabulate the Mellin transform and its inverse, respectively. From these entries many others may be obtained by the usual techniques of specialization of parameters, differentiation and integration with respect to a parameter, and application of transform rules.

This is the first work of such wide scope. There are several satisfactory tables of Laplace transforms, though none are as extensive as that in present volume. The standard reference for Fourier transforms by Campbell and Foster was compiled in 1931, but later editions do not include additional material. The literature has been void of extensive tables of Mellin transforms. Thus present volume fills an important need and is a welcome addition to the workshop of the theoretical and applied scientist.

Y. Luke, USA

2057. Courant, R., and Hilbert, D., Methods of mathematical physics, Vol. I, 1st English ed., New York, London, Interscience Publishers, Inc., 1953, xvi + 561 pp. $9.50.

This translation of the German original will be heartily welcomed by workers in applied mechanics and applied mathe-

matics. Professor Courant notes that demand for an English edition was sufficient to cause him to postpone a complete rewriting of the book in favor of a translation. Latter was prepared by Courant and many collaborators and follows the German edition quite closely. Some modifications and additions have been made, including a new section in chap. IV (Variational calculus), on reciprocal quadratic variational problems; an appendix to chap. VII, on transformation of spherical harmonics; and a list of additional bibliographic material, divided by chapter.

J. L. Lubkin, USA

2058. **Cochran, W. G., Sampling techniques,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1953, xiv + 330 pp. $6.50.

This is an excellent survey of the fundamental principles underlying the field of sample surveys. In this book the author gives methods of sample selection and estimation which provide estimates of a specified precision at the lowest possible cost. This idea of getting a specified precision at minimum cost is back of all sampling plans. Optimum methods of choosing samples are given under a wide variety of situations arising in practice. Considerable attention is also focused on the chief sources of error and bias in a survey.

The many examples scattered throughout the book illustrate the key principles of sampling very well. A person who has had a year's introductory course in statistics should have no difficulty mastering this book and making use of the theory in it.

B. Epstein, USA

2059. **Purcell, E. W., The vector method of solving simultaneous linear equations,** *J. Math. Phys.* **32,** 2–3, 180–183, July–Oct. 1953.

Author makes the n equations homogeneous and takes the coefficients as coordinates of vectors $V_1, V_2, \ldots V_n$. He then takes n vectors orthogonal to V_1, then by linear combination finds $(n-1)$ vectors, all of which are orthogonal to V_1 and V_2, etc. The method has advantages when equipment such as the IBM card-programmed calculator is available. The number of multiplications needed is given by $(1/6)n(n-1)(2n+5)$, which is the same as for the Crout method. O. Bottema, Holland

2060. **Walsh, J. L., and Young, D., On the accuracy of the numerical solution of the Dirichlet problem of finite differences,** *J. Res. nat. Bur. Stands.* **51,** 6, 343–363, Dec. 1953.

Paper gives numerical bounds for the error in certain closed regions for the difference of the difference analog of the Dirichlet problem and the solution of the Dirichlet problem. The bounds depend on mesh size and the oscillation and modulus of continuity of function on the boundary. Value of paper is that bounds are independent of higher partial derivatives which are usually difficult to estimate even from the work sheet. Further, it may happen that although partial derivatives in question are unbounded, solution of difference equation may still converge to solution of differential equation. The problem for the rectangle is treated in detail. Overlapping rectangles are also considered to illustrate extension of method to more complicated regions. Paper would have been enhanced by inclusion of a numerical example.

Y. Luke, USA

2061. **Van Wijngaarden, A., A transformation of formal series. I, II,** *Proc. k. Ned. Akad. Wet.* (*A*) **56,** 5, 522–543, Nov.-Dec. 1953.

In the computation of functions by series, it is well known that an ascending series is useful if the argument is not too large. For large values, an asymptotic expansion is usually available. Difficulty in computation usually arises where neither expansion is convenient. Purpose of paper is to develop a theory for transformation of series to fill this gap. A number of examples are provided. Application of theory depends on pretabulation of certain functions, and these are promised for a separate communication.

Y. Luke, USA

2062. **Edman, J. L., Graphical solution of simultaneous second order non-linear differential equations,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 170–174, Apr. 1953.

Author describes a graphical method for solving a simultaneous system of nonlinear equations of the form $\ddot{x}_i + F_i(\dot{x}_1, \ldots, \dot{x}_n, x_1, \ldots, x_n, t) = 0$, $i = 1, 2, \ldots, n$, where dots stand for differentiation with respect to time. Making use of the substitution $d\dot{x}_i/dx_i = \ddot{x}_i/\dot{x}_i$, the system reduces to one which can be used to construct the phase space curves $\dot{x}_i$ vs. x_i. The curves F_i together with the phase space curves are used to determine the solutions.

The validity of solutions of nonlinear systems has been checked by solving linear systems. Reviewer doubts that the validity of solutions of nonlinear systems can be checked in this manner. Correlation with laboratory results was found to be fairly good and this seems a better check than the afore-mentioned method.

A relatively simple system of two equations governing the dynamical behavior of a landing gear mounted in a drop rig was used to illustrate the method. E. J. Scott, USA

2063. **Ku, Y. H., A method for solving third and higher order nonlinear differential equations,** *J. Franklin Inst.* **256,** 3, 229–244, Sept. 1953.

Author gives a general method for solving nonlinear differential equation of the form $x^{(n)} + \Phi_{n-1}x^{(n-1)} + \ldots + \Phi_2 x^{(2)} + f(x^{(1)}, x) + f_1(x) = F(t)$ where $x^{(i)}$ is the ith derivative with respect to t: Φ_i is a nonlinear function of $x^{(i)}, x^{(i-1)}, \ldots$ and eventually t.

The solution is constructed from generalized phase-plane equations, which are derived from the given differential equations. The method is applied to a third-, fourth-, and sixth-order equation. J. W. Cohen, Holland

2064. **Mikeladze, Sh. E., Theory of the construction of interpolation formulas** (in Russian), *Doklady Akad. Nauk SSSR* (*N.S.*) **90,** 4, 503–506, June 1953.

Let $y(a + ht_\beta)$ be given by a Taylor-series expansion employing derivatives at $a + ht_\alpha$. If remainder is expressed in integral form, different interpolation formulas follow, using different approximations for the derivative appearing behind latter integral. The interpolating polynomials may be changed, or certain values may be assigned t_α and t_β. Also, the remainder may be found by a numerical method. For example, $f(a + th)$, the nth derivative of y, is computed by a generalization of Newton's interpolating polynomial using both forward and backward differences. A generalization of Stirling's interpolation formula is gained (Eq. [3] of author), going first horizontally from $f(a)$ to $\Delta^{2p}f(a - ph)$ and then in a diagonal direction to $\Delta^r f[a - (r-p)h]$, $r \geq 2p + 1$, using the average of differences appearing below and above the horizontal path. Technique is the same as used to derive Stirling interpolation formula from that of Gauss [e.g., F. A. Willers, "Methoden der praktischen Analysis," Berlin, p. 78, 1928].

Also considered is repeated differentiation of Eq. [1] of the author, using Mikeladze [*Usp. matem. Nauk* **3,** 6, 1948] and thus obtaining the formula due to Markoff.

Author states that several interpolation formulas in book of L. Collatz, "Numerische Behandlung von Differentialgleichungen," 1951 [AMR **5,** Rev. 1598] were first given by Mikeladze [*Izv. Akad. Nauk SSSR Ser. Matem.* no. 5–6, 1939] or are special ex-

amples of such formulas of Mikeladze, reviewed by Collatz in *Zbl. Math.* **24,** 6, p. 269, 1941. H. Schlechtweg, Germany

2065. Fowler, C. M., Symmetry as a factor in finite difference approximations, *J. appl. Phys.* **25,** 3, 293–294, Mar. 1954.

The effect of symmetry of the solutions to the finite difference equation upon the stability criterion is discussed. A simple example is included to illustrate the discussion.

From author's summary

2066. Reswick, J. B., Scale factors for analog computers, *Prod. Engng.* **25,** 3, 197–201, Mar. 1954.

A technique is developed which permits a simple visualization of the scale factor problem in analog computers. This method allows the operation of time scaling to be considered apart from scale factor determinations. Both operations become routine, simple, and fast. A typical problem is shown to illustrate the technique. From author's summary

2067. Belgrano, J. C., Nieto, A. L., and Urcelay, J. M., Nomography [Tratado de nomografia], Madrid, Instituto Tecnico de la Construccion y del Cemento, 1953, xii + 387 pp. 125 ptas.

Detailed presentation and discussion of all known theories, complete with new results and numerous original examples. Chap. I deals with general matters such as fundamentals, visual interpolation errors, practical rules of graphs, types of nomographs, fundamental problems, anamorphosis, completing Lafay's results. Chap. II discusses relations with two and three variables, trirectilinear, circular, etc., arrangements as suggested by various authors, full investigation of charts with more than three variables, solution of the problems of analytical and tabular identification, ramified charts. Chap. III gives a detailed account of alignment charts, refers to investigations by d'Ocagne, and presents a detailed study of tangential types of charts with valuable applications. Chap. IV describes charts with transparent sheets, made of an angle, or parallel lines, or proportional scales, with numerous original investigations, which are also included in chap. V. Appendix contains chart description of simultaneous systems of equations, graphical calculation charts, and other possibilities of this "rationalization of calculation."

The book is indispensable for study and application of nomography. References are given to following authors: Alloock and Jones, Baró, Brodetsky, Frechet-Roulet, Cercevanoff, Luckey, Soto Hidalgo, Willers, Margoulis, Schwerdt, Boulanger, Lambert, Soreau, d'Ocagne, and others.

Among significant original results of authors' study presented in this book the following should be especially mentioned: (1) Development of a new type of intersection charts based on superposition of families of curves; (2) Omission of transparent sheet in those charts that previously needed one; (3) Development of two new types of charts (baricentric and rhomboidal charts); they don't need transparent sheet and their key is based on metric relationships; they can represent the same type of formulas as are describable with charts fitted with a transparent sheet, which moves without rotation; (4) Representation of three double-entry tables, of special interest as means of parabolic interpolation; (5) Construction of approximate charts for certain types of series of double-entry tables. J. J. Polivka, USA

2068. Hjelmström, P., Measurement of volume with a stereoscopic instrument (in Swedish), *Tekn. Tidskr.* **43,** 83, 919–920, Nov. 1953.

A principle is presented for estimating volume of real objects by aid of a stereoscopic picture. A stereoscopic analyzer with moving dot slices the object by equidistant planes, the areas of which are automatically measured by planimeter mechanically connected to analyzer. Certain limitations arise from unsuitable form of object. Local volume change can be calculated from exposures before and after deforming. Reported application is measuring tumefactions, error being less than 10%.

J. Hult, Sweden

2069. Morton, G. F., and Gough, V. E., The optical projection of the profile of an article at a given cross-section, *J. sci. Instrum.* **30,** 8, 277–280, Aug. 1953.

Two types of projector are described which permit the continuous observation of the sectional shape of a rodlike or threadlike object, of substantially constant cross-sectional shape, as the object is passed through the projector. The article may be of any length and may be flexible or rigid. From authors' summary

Mechanics (Dynamics, Statics, Kinematics)

(See also Rev. 2225)

2070. Technology of mechanisms [Getriebetechnik], VDI-Tagungsheft 1, introduction by H. Alt, VDI-Tagung, Berlin, 1951 edition, 200 pp., 260 illus.; Duesseldorf, Deutscher Ingenieur Verlag, 1953. DM 15.80.

Publication contains most of the papers presented at the first German postwar conference on this subject. Besides theoretical questions, problems of practical engineering are dealt with; some contributions to the discussion are given. Papers are not reviewed in the order given in the publication, but alphabetically according to author.

The brochure has a preface by H. Alt, chairman of the special committee of mechanisms of VDI. He also contributed three papers. First, he gives recommendations for the design of periodic mechanisms for which cam and link mechanisms are available. He shows that, in some instances, cam mechanisms can be replaced by linkages (pp. 27–32). Alt, who introduced the pressure angle (Uebertragungswinkel) to link mechanisms, also writes on the quality of the transmission of movements (pp. 113–115). Finally, he discusses the problem of making models for mechanisms and, from his own experience, gives hints on how models can be made in a simple way with available materials or unit-type models developed (pp. 197–200).

F. G. Altmann reports on steplessly variable mechanisms, comparing new with older types. He distinguishes between friction gears with spherical and conical friction elements, friction band drives with vee-belts, positive drives with lamellae chains, and variable speed gears with ratchets (Schaltwerksgetriebe). In the discussion, W. Thomas prefers drives with pure "rolling" instead of rolling and sliding (pp. 1–10).

Altmann deals (pp. 51–68) with special forms of link mechanisms in space and their limitations [published previously in *Konstruktion* **4,** pp. 97–106, 1952]. Starting from the general conditions of positive mechanisms in space, special mechanisms are derived with a reduced degree of freedom, such as the Bennett mechanism. Among the many solutions treated are self-locking mechanisms, reverting mechanisms, and angular drives.

R. Beyer considers the threefold coaxial-screw mechanism as a wedge mechanism and on this basis derives the necessary formula for describing its operation. A table for determining the dimensions is also developed (pp. 149–163).

The design of cams for production machines is discussed by H. Brandenberger, with particular stress on the acceleration, taking the Coriolis acceleration into account (pp. 21–26). He also supplies a contribution to the vexing question of the efficiency of

self-locking planetary drives when driven in the opposite direction. To this, H. Strauch (see later on) supplies a further contribution (pp. 69–76).

K. Federhofer in a short note discusses the use of the inertia pole curve (Traegheitspolkurve) for solving the dynamics of the centric crank drive (pp. 101–102).

P. Grodzinski (pp. 81–100) presents a number of new reciprocating mechanisms which give a constant velocity during the stroke. After giving some basic data, the following possibilities are discussed: Eccentric spur wheels, universal links, a mechanism suggested by F. Reuleaux as a coupling, the Bennett linkage. Further, as an example of a mechanism producing a swinging movement of approximate constant angular velocity, a six-bar linkage derived from the centric mechanism is discussed with several special solutions; for instance, as reverting coaxial mechanisms. Other possibilities, for example hydraulic or electric control, are indicated.

K. Hain demonstrates the application of linkages in the design of agricultural tractors (pp. 127–134).

Mechanisms applied in glass-working machines are discussed by E. Kammel (pp. 127–134).

G. Kiper (pp. 103–112) shows a number of methods for designing linkages with six and more members for given conditions (being an extract from his doctorate thesis, Technische Universitaet, Berlin-Charlottenburg, 1949, and of *VDI-Forschungsheft* 433, 1952).

R. Kraus contributes a short paper on a new evaluation method (Wertigkeitsbilanz) (pp. 195–196). Contrary to other attempts, he uses for this purpose the ordinates which are available for the fulfillment of special conditions.

W. Lichtenheldt (pp. 33–40) demonstrates that the recommendations for the design of straight line movements as contained in the German engineers' handbook Huette [in particular, 27th ed., **II**, and in a number of previous editions] need revision in the light of modern knowledge.

P. Lohse (pp. 124–126) contributes to the lubrication of periodic mechanisms.

A rather condensed survey on the mechanisms in textile machines is given by F. Oertel (pp. 41–46).

The late K. Rauh shows how the harmonic movement (pp. 47–50) in simple crank drives can be influenced to conform with given conditions.

He demonstrates (pp. 135–140) what he calls harmonic synthesis of mechanisms for determining coupler curves for arbitrary laws of movement. This is an amplification of methods given in his "Praktische Getriebelehre" **I**, 2nd ed., 1951.

K. Reinecke (pp. 165–178) describes the development of the type-operating lever mechanisms for typewriters, considering also dynamic aspects, in particular noiseless mechanisms.

K. Schnarbach deals with the design of rod ends, forks, and bolts for cam and link mechanisms and shows a number of practical solutions (pp. 117–120).

K. H. Sieker tells about the tolerances in mechanisms, in particular how they influence the accuracy of the transmission of movements in cam ramps (pp. 121–123).

In another paper (pp. 141–148), Sieker deals with spring joints and mechanisms utilizing springs.

H. Strauch (pp. 77–79) discusses generally the "self-locking" of planetary gear. He considers the self-locking as an academic question and suggests approaching it by experiment design.

P. Wildt (pp. 11–20) presents his ideas for the generation of cam ramps in which an intermittent motion, for instance by a Maltese cross, is combined with planetary gears in the form of a differential. He demonstrates various types of cam ramps obtainable in this way without a template.

P. Grodzinski, England

2071. Pailloux, H., New applications of functional calculus to mechanics (in French), *Ann. sci. École norm. sup. Paris* (3) **70,** 1–49, 1953.

Author applies the method described in a previous paper [AMR **6,** Rev. 2679] to the statics and dynamics of plate and shells and also to problems of a more technical engineering nature involving systems of beams, such systems being replaced by continua. There is also an application to hydrodynamics. The object is to obtain differential equations rather than to solve them, and the method (which is essentially an energy method) may be described by considering the equilibrium of a shell, omitting body forces and surface forces (they are included in the paper, which also deals with dynamics). The strain energy is an integral involving the first derivatives of the displacement (u, v, w), and the condition that this integral shall be stationary gives, of course, the usual equations of elastic equilibrium. But instead of using a general displacement the author takes [*] $u = u_1 + \zeta u_2$, $v = v_1 + \zeta v_2$, $w = w_1 + \zeta w_2$, where $(u_1, \ldots w_2)$ are functions of (x, y) and ζ is the distance of the point in question from the mean surface of the shell, measured parallel to the z-axis. This restriction on the displacement is justified by the thinness of the shell. The strain energy for [*] is an integral of the form $\int\int \ldots dx\, dy$, since ζ disappears on integration across the thickness of the shell, and, when the stationary condition is applied to this integral, we get partial differential equations for $(u_1, \ldots w_2)$ with (x, y) as independent variables. Thus the method is one in which approximate equations are obtained from an exact variational principle by restricting the functions involved to a certain type.

J. L. Synge, Ireland

2072. Tolle, O., Contribution to the graphical dynamics of the plane crank mechanism (in German). *Motortech. Z.* **15,** 2, 46–49, Feb. 1954.

First, a survey is given of known solutions by K. Federhofer, F. Wittenbauer, and O. Mohr of the following problem: To determine the acceleration, the forces due to mass effects, as well as the forces in the links and the slide of a plane crank mechanism (mainly centric slider crank mechanism), when, for given velocities and mass distribution, the external forces (driving forces and produced forces) are known. The movement of the mechanism is, following O. Mohr, considered to be composed of two part-movements, (1) due alone to the velocity conditions of the mechanism (a member rotating about a fixed center has angular acceleration $\epsilon = 0$, and a known angular velocity ω), (2) due to a movement starting with $\omega = 0$. Mohr determined the unknown angular acceleration of (2) by calculation, whereas in this paper a graphical solution is given. Instead of using several dynamic substitute points for the mass reduction, here the mass is reduced for each link separately, using new solutions. Use is made of velocity vectors turned by 90 deg according to the kinematical method of Mueller-Breslau. In this method the position of the pole (with $v = 0$) must be known, but two new substitute solutions are shown for the frequent case where the pole is not accessible.

Paper is a valuable contribution to the knowledge on this subject.

P. Grodzinski, England

2073. Krzywoblocki, M. Z. v., On the so-called principle of least work, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 43–48, Apr. 1953.

By means of the well-known principles of dynamics and statics, author shows that there exists a continuous sequence of mathematically equivalent equations, thus proving that any problem involving the variation of strain (or stress) energy alone must be solved by means of fundamental equations of the calculus of variations. The methods applying the so-called principle of least

work and some minimizing sequence are shown to be, beyond any doubt, the Ritz method applied to stress (or strain) energy alone. Some considerations on the subject of the convergence of a minimizing sequence applied to two kinds of variational expressions close the paper. From author's summary

2074. Hall, A. S., and Tao, D. C., Linkage design, a note on one method, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-142, 10 pp.

Svoboda ["Computing mechanisms and linkages," McGraw-Hill, New York, 1948, p. 199 et seq.] has shown that, in general, for small changes in the K disposable parameters p_n of a linkage, an improvement to a tentative design giving an output S as against a desired output S_0 can be effected by solving the simultaneous equations

$$e = S_0 - S = \sum_{n=1}^{n=k} (\partial S/\partial p_n)\Delta p_n$$

In most cases, the determination of the terms $\partial S/\partial p_n$ is inconvenient and laborious. Authors therefore propose that these should be obtained graphically by means of vector velocity diagrams using the relation $\partial S/\partial p_n = (dS/dt)/(dp_n/dt)$.

Authors suggest that this may enable method to be extended to more complex linkages than 4-bar chain, but give only simple 4-bar examples. E. M'Ewen, England

2075. Rosenauer, N., On the acceleration analysis of complex mechanisms, *J. Instn. Engrs., Austral.* **25,** 12, 235–237, Dec. 1953.

Author states, "the acceleration analysis for any mechanism having constrained motion driven by any link is always possible by means of relative accelerations." Thesis is supported by geometrical solutions for the motions of points in three planar floating-link mechanisms considered unsolvable by other authors. C. M. Ablow, USA

2076. Starzhinskiĭ, V. M., Stability of a certain mechanical system with one degree of freedom (in Russian), *Prikl. Mat. Mekh.* **16,** 1, 117–122, Jan.-Feb. 1953.

Author extends Lyapunov's method for the stability of motion to the mechanical system with one degree of freedom and constant dissipation, governed by equation $y'' + ay' + p(x)y = 0$, where $a > 0$, $\omega > 0$, $p(x + \omega) = p(x) \geq 0$.

The solutions $f(x)$ and $\varphi(x)$, with initial conditions, are found by means of the multiple integrals of the different values x_i of the variable x. These are the new variables, subjected to the condition $x > x_1 \ldots > x_{2n} > 0$. Three values of the coefficient $A = [f(\omega) + \varphi'(\omega)]/(1 + e^{-a\omega})]$ are calculated. For $a = 0$, the result coincides with Einaudi's result [*Atti Ist. Veneto Sci.* **95**, 1936]. However, Lyapunov's inequality $A_n^2 > [nA_{n-1}A_{n+1}]/(n - 1)$, $n \geq 2$, is not confirmed; for that reason his method is not applicable in this case.

The derived relations are applied to the equation $y'' + ay' + C(1 + \lambda \cos x)y = 0$, $a = \omega\alpha/2\pi$, $C = \omega^2/4\pi^2$ [AMR **6**, Rev. 346]. The zones of the stability are shown graphically in the system of the parameters (C, a, λ).

Reviewer thinks that the author's example may be reduced, by the change $y = ze^{-ax}$, to Mathieu's equation $z'' + C(1 + \lambda \cos x)z = 0$ [N. W. McLachlan, "Theory and application of Mathieu functions," Oxford, 1947]. D. Rašković, Yugoslavia

2077. Hayes, W. D., On the equation for a damped pendulum under constant torque, *ZAMP* **4,** 5, 398–401, 1953.

It is known that for the differential equation of the damped pendulum under constant torque $\vartheta'' + \alpha\vartheta' + \sin\vartheta = \beta$ (α, β positive real constants) there exists a positive number $\alpha_0(\beta)$ such that the equation has a periodic solution of the second kind (that is, a solution $\vartheta(t)$ subject to the conditions $\vartheta'(t) > 0$ and ϑ' periodic in ϑ) if and only if either (a) $\beta > 1$ or (b) $0 < \beta < 1$ and $\alpha < \alpha_0(\beta)$.

The present note is concerned with the derivation of an upper and lower limit for $\alpha_0(\beta)$. H. L. Oestreicher, USA

2078. Wellinger, K., and Uetz, H., Friction and wear experiments on unhardened and tempered steel plate used for transport channel (in German), *ZVDI* **95,** 26, 906–910, Sept. 1953.

For transportation of goods shipped in bulk, transport channels are sometimes used. These channels guarantee safe and economic working if materials of low friction and wear are used for the lining of the charging chute.

The results of friction and wear experiments on unhardened and tempered steel plate are given and compared with each other in diagrams and tables. The experiments are designed to give conditions of friction and wear similar to those of steel plate in a transport channel.

In the experiments for wear, consideration is given to the hardiness, the velocity of gliding, the size of the grains, and the influence of the percentage of water. A. Slibar, Austria

Servomechanisms, Governors, Gyroscopics

2079. Eckman, D. P., Phase-plane analysis—a general method of solution for two-position process control, *Trans. ASME* **76,** 1, 109–116, Jan. 1954.

Author outlines procedure of solution of two-position process-control problems characterized by second-order differential equations through use of phase-plane analysis. Details, such as graphical exhibition of amplitude of steady-state oscillation, are effected for five particular cases. Author comments on Ziegler-Nichols' approximation and illustrates its application by three examples. T. J. Higgins, USA

2080. Nies, P. L., Automatic control—principles of feedback and their application in machine control, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-140, 6 pp.

Paper gives an extremely elementary account of the principles of automatic control systems, with special reference to machine control. The object of the paper is not clear in view of the extensive literature and the several excellent books on the subject now available. A. Porter, Canada

2081. Lee, S. Y., Contributions to hydraulic control—6. New valve configurations for high-performance hydraulic and pneumatic systems, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-139, 10 pp.

In high-performance hydraulic (and some pneumatic) servos it may be desirable to have valves with practically zero lap (i.e., neither positive nor negative), which requires very high manufacturing accuracy. Methods of achieving this are reviewed, e.g., making the sleeve of a cylindrical slide valve in several pieces, and are stated to be difficult and expensive, although reviewer believes these difficulties tend to be overrated. Paper describes what is claimed to be a cheap and easy method of making valves with nominally zero lap. In essence, controlling edges of valve are determined by a pair of holes in valve body and another pair in valve slide; these are finished on assembly and therefore coincide accurately in diameter and center distance. Typical flow curve is given for a valve on this principle. Valves may be sliding or rotary. There may be a single pair of flat surfaces, with slide or spring suspension giving substantially parallel movement and re-

sisting transverse pressure force, or there may be a pair of flat surfaces giving nominal balance of transverse forces. In latter case, residual transverse forces causing friction still remain [AMR 6, Rev. 3278] and methods of avoiding this effect are proposed—these methods are not novel to reviewer [see, e.g., H. G. Conway, "Fluid pressure mechanisms," Pitman, 1949, fig. 50]. Hydrodynamic forces may be reduced by an arrangement similar to that proposed for orthodox valves by author and J. F. Blackburn [AMR 5, Rev. 1116]; an alternative arrangement which is easier to make is also described. This is stated to "work very well" but no quantitative results are quoted. Basic principle of construction is also shown in application to circular cylindrical slide and rotary valves; reviewer suggests these may be inferior to flat surface valves described, as balance is imperfect unless drillings pass accurately through axis of bore.

R. Hadekel, England

2082. **Gerassimow, S. G., Dudnikow, E. G., and Tschistjakow, S. F., Automatic control of boiler plants [Automatische Regelung von Kesselanlagen].** Berlin, Verlag Technik, 1952, 353 pp. $8.40.

This volume, published in the East zone of Germany, is a translation from Russian to German by Waldemar Beck of a book that originally appeared in 1950. After a historical introduction devoted largely to Russian contributions to the subject of automatic control, the writers develop some of the fundamental theory of regulators, giving both differential equations and physical examples. Starting with a simple on-off water-level control, the theory is extended to more complicated configurations involving direct and elastic feedback with and without relays.

Hurwitz, Michailow, and Nyquist criteria for stability are given. Michailow is credited with being the first to recognize (1938) the use of Nyquist's criterion for automatic controls. The book is also concerned with the computation of overswings and curves representing transient responses.

After this introduction to the subject, the major types of automatic controls used in heat-transfer processes are described. Hydraulic, pneumatic, electromagnetic, and electronic regulators for the control of pressure, temperature, and other variables are treated in considerable detail, with a brief section on a speed governor for steam turbines. The book concludes with the application of these controls to boilers and auxiliaries in steam plants.

Reviewer believes that the book is a good, though classical, treatment of information of value to engineers concerned with steam power plants.

R. Oldenburger, USA

Vibrations, Balancing

(See also Revs. 2077, 2101, 2325, 2341)

2083. **Pipes, L. A., Analysis of a nonlinear dynamic vibration absorber,** *J. appl. Mech.* **20,** 4, 515–518, Dec. 1953.

Paper analyzes the steady-state behavior of a dynamic vibration absorber consisting of a main mass attached to a rigid foundation by a linear spring and coupled to an absorber mass by a spring of nonlinear characteristic expressed by a hyperbolic sine.

The fourth-order nonlinear differential equation for the relative amplitude, resulting from the force analysis, is solved by the use of Duffing's method of assuming a one-term approximation to the periodic steady-state solution. The nonlinear spring force is expressed in terms of harmonic components, the coefficients of which are the modified Bessel functions of the first kind and order n. The relative amplitude equation is obtained by equating the coefficients of the first harmonic component.

Solutions of the amplitude equation are obtained analytically for two specified values of the exciting frequency. For the more general case a graphical procedure is outlined. The amplitude of each mass is found to contain odd harmonics which converge rapidly. The possibility of a jump phenomena for large exciting frequencies is indicated. The nonlinear characteristic of the spring chosen results in large absorber forces for finite amplitudes and prevents the existence of sharp resonant peaks.

W. T. Thomson, USA

2084. **Morduchow, M., On application of a quasi-static variational principle to a system with damping,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-3, 3 pp.

The principal bending modes of vibration of a beam with a damping force proportional to the velocity are considered. It is shown that, in an important class of cases, the damping has exactly no effect on the mode shapes. It is further shown that the linear differential equation for the vibrating beam with damping can be transformed into a stationary condition after eliminating the time as a variable. Application of the Rayleigh method to this condition then leads to general approximate results for the logarithmic decrement and for the effect of damping on the natural frequency, not only in the fundamental mode but also in any higher principal mode.

From author's summary by W. L. Esmeijer, Holland

2085. **Chopin, S., Comparison of different theoretical formulas giving generalized masses in the practical case of a vibration test of an airplane** (in French), *Rech. aéro.* no. 35, 49–52, Sept.-Oct. 1953.

Author investigates difficulties met in attempts to deduce generalized masses (i.e., inertia coefficients in Lagrange equations of motion in normal coordinates) from resonance test measurements. Analysis is, in parts, far from clear to reviewer.

J. H. Greidanus, Holland

2086. **Young, D., Forced vibration of system with nonlinear restoring force,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 164–169, Apr. 1953.

The REAC analog computer was used to study Duffing's equation. Amplitude and phase of steady motions having same period as the excitation are recorded and compared with existing approximate theory. Agreement is good for small amplitude motions. For large amplitudes, some anomalies are noted. In particular there is a range of frequencies for which the stable response is an unsymmetric oscillation. This is qualitatively correlated with a stability theory for symmetrical motions, which indicates that symmetric oscillations would not be stable in this same range.

S. H. Crandall, USA

2087. **Trumpler, W. E., Jr., and Owens, H. M., Turbine blade vibration and strength,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-98, 10 pp.

Failures of turbine blades are the most frequent source of damage in steam turbines and, therefore, every progress made is important. This short paper discusses only vibrations and strength of blade rows of the full admission type. A summary gives the sources of excitation of the blade vibrations by steam flow in which, in opinion of reviewer, only the influence of the vanes following the rotating blades is left out. For the present, vibrational stresses cannot be calculated accurately because the magnitude of excitation and damping are known qualitatively only and further research is necessary. On the other hand, the designer needs a guide to design untuned blades. For this purpose an empirical approach is given, which permits controlling

approximately the steady steam bending stress of the blades in dependence on the harmonics under consideration of centrifugal stress, endurance limit of material, and stress concentration factor. Tuned blades must be designed to avoid harmonics of the running speed and, therefore, it is necessary to calculate and measure the frequencies of the various natural modes of vibration. The stiffening effect and the change in blade-root tightness in consequence of rotation and the disk effect must be respected. In such a short article it is not possible to say all on this difficult problem, but the most important factors are mentioned. Paper will be of great interest for calculators and designers of steam turbines. P. Kohn, Czechoslovakia

2088. Saxon, D. S., and Cahn, A. S., Modes of vibration of a suspended chain, *Quart. J. Mech. appl. Math.* **6,** part 3, 273–285, Sept. 1953.

Authors set out to determine analytically the frequencies and modes of a uniform inextensible chain catenary in its own plane. Like Pugsley in his semiempirical approach, they use the linearized form of the equations of motion used by Routh for studying small-amplitude displacements from the static catenary. By regarding these displacements as transverse displacements from the tangent to the catenary, they develop an iterative method that gives asymptotic solutions to any required degree of accuracy. Very satisfactory agreement with experimental results are shown even for deep catenaries.

D. Williams, England

2089. Davidson, J. F., The vibration of a slightly curved bar carrying an end mass, *Publ. int. Assn. Bridge struct. Engng.* **13,** 87–94, 1953.

Beam analyzed is uniform, slightly bent into a half sine wave, and simply supported with a concentrated mass attached to the movable end. Oscillatory deflections are assumed small relative to misalignment which, in turn, is assumed small relative to length. Formulas are given for two lowest frequencies in terms of natural axial frequency of weightless straight beam with end mass and first natural lateral frequency of uniform straight beam. Coupling of the elementary motions is due to misalignment. Numerical example is given. S. U. Benscoter, USA

Wave Motion, Impact

(See also Rev. 2124)

2090. Bishop, R. E. D., and Goodier, J. N., On Eulerian coordinates in elastic wave propagation, *J. Mech. Phys. Solids* **2,** 2, 103–109, Jan. 1954.

In problems on elastic wave propagation the usual treatment assumes that the disturbance travels through the stationary body. This approach, of course, is appealing from a physical point of view. The authors, however, are concerned with the alternate approach, where the body is assumed to move through the fixed wave. It is their purpose to point out the prominent features of the method.

The transverse motion of a long, flexible, taut string is used as an introductory problem. Equations of motion are then derived for the case of the homogeneous, infinite, elastic solid, moving along the x-axis under a constant velocity.

The method finds particular usefulness in steady-state motions, where it is pointed out that solutions to the governing equations can be obtained with the aid of potential functions. These functions, which are functions of x, y, and z only, are associated with the dilational and distortional components of the displacement form. The plane strain case is treated as an example.

J. Miklowitz, USA

2091. Harron, R. J., A waveform generator, *Nat. aero. Establ. Canada* LR-80, 18 pp.,Oct. 1953.

The instrument described is capable of generating any desired wave form at recurrent frequencies between 2 and 70 cps. An outline of the desired wave form is cut from a sheet of opaque material and inserted in a slot located between a phototube and a cathode-ray tube. The output voltage is dependent on the height of the wave-form mask and reaches a maximum of 80 volts peak-to-peak across an internal impedance of 10,000 ohms.

From author's summary

2092. Campbell, W. S., An electronic wave-height measuring apparatus, *David W. Taylor Mod. Basin Rep.* 859, 15 pp., Oct. 1953.

This report describes briefly the salient features of new instrumentation for measuring and recording wave amplitudes and wave forms of water waves. Because of the increased accuracy and flexibility afforded by the instrumentation described, it has replaced other techniques which were formerly used.

The gaging element of this system consists of extremely small insulated wire suspended rigidly upright in the water. The conductor acts as one plate of a capacitor and the water in which the gaging element is partially submerged acts as the other; the insulation material on the wire forms the dielectric of the capacitor. The capacity of this "condenser" (measured between the conductor and water) is directly proportional to the linear length of the submerged portion of the wire. This capacitor is connected in one arm of a resonant-bridge circuit, which may be balanced for the quiescent level of the water. Variations in water height, which occur as waves pass the gaging element, produce capacitive unbalance of the a-c bridge in each sense, and the direction of unbalance is recovered by a more or less conventional phase-sensitive demodulator circuit incorporated in the circuit of the wave-height recorder.

From author's summary

2093. Hunt, J. N., A note on gravity waves of finite amplitude, *Quart. J. Mech. appl. Math.* **6,** part 3, 336–343, Sept. 1953.

Note concerns corrections to Struik's paper on traveling waves [*Math. Ann.* **95,** p. 595, 1926] and leads to corrected expressions for wave profile and speed of propagation.

W. Freiberger, Australia

2094. Kasahara, K., Experimental studies on the mechanism of generation of elastic waves, I, II, III, *Bull. Earthq. Res. Inst., Tokyo Univ.*, **30, 31,** 3, 1, 3; 259–268, 2 plates; 71–78, 235–243, Sept. 1952, Mar., Sept. 1953.

Part I. Author describes the use of a block of agar-agar jelly as the transmitting medium in an experimental study of elastic waves. The elastic constants were determined statically. Transient disturbances in the jelly were provided by the vertical motion of a bar lying in contact with the free surface and driven electromagnetically. A capacitor, of which the elastic medium formed one plate, was used as a detector of surface displacements. Horizontal surface displacements in the direction of propagation were measured in this way by scooping out a trench in the jelly. Records were obtained on an oscilloscope. Observations were made of displacements and exciting current for various distances between exciter and detector.

Results are analyzed in the light of wave velocities calculated from elastic constants, and comparisons are made with results due to Lamb [*Phil. Trans. roy. Soc.* (*A*), **203,** 1, 1904] with fair agreement. Some discussion is given of motion at the surface near the source where an initial upward displacement was noticed.

Reviewer observes that the choice of material is difficult and that agar-agar is not ideal for this purpose. Also, a jelly might provide means of investigating motion within an elastic solid, whereas the author confines attention to the surface. This important paper is somewhat marred by sketchy discussions of technique and results.

Part II. Author examines theoretically the initial upward motion of the surface close to the source that was observed in the above experiments. The two-dimensional problem is treated of the surface displacement caused by an impulsive, distributed, downward force applied to the surface of a semi-infinite solid. Operational methods are used, and displacements near the source are found numerically. Results indicate the initial surface swelling as observed, but appear not to agree with other features of the experimental records.

Reviewer believes that, owing to the scarcity of data on conditions near sources of disturbance, a more complete investigation would be welcome. Comparison of this theory with the experiments should not be pushed far in view of obvious discrepancies; for instance, agar-agar was chosen for its high viscosity, whereas a frictionless solid is postulated in the theory.

Part III. This is a continuation of part I. The same apparatus was used except that the disturbing mechanism was replaced by a horizontal bar supported on soft rubber packing just below the surface of the jelly. The bar was given oscillatory motions of short duration simultaneously in perpendicular and lateral directions; these had the same frequency and amplitude but variable phase. The system was essentially two-dimensional.

Particle motions at the surface were observed, as before, at different distances from the exciter. These conformed roughly to the impressed motion close to the disturbance and became more nearly those of free surface waves at greater distances.

The paper concludes with a discussion of strain energy in Rayleigh waves. R. E. D. Bishop, England

2095. **Rubin, R. J., Some problems connected with propagation of stresses above yield stress in a material exhibiting a strain-rate effect,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 133–135, Apr. 1953.

Author considers case for which equations of motion of a thin rod under monotonically increasing loading force are linear, i.e., the static stress-strain curve for the material consists of two straight-line segments which intersect at the yield point and the rod is semi-infinite and is prestressed to the yield point. The two special loading forces considered are a force that moves the end at constant velocity and a force of form $P[1 - \exp(-bt)]$. The unloading case is considered for instantaneous load removal. Results for stresses and displacements are in terms of the complex inversion integral of the Laplace transformation.

B. E. Gatewood, USA

2096. **Dengler, M. A., Goland, M., and Wickersham, P. D., Propagation of elastic impact in beams in bending,** ASME Ann. Meet., New York, Dec. 1953. Pap. no. 53—A-46, 8 pp.

See AMR **6,** Rev. 3666.

2097. **Carry, C., Partial clapotis** (in French), *Houille blanche* 8, 4, 482–494; Suppl. no. 4, Aug./Sept. 1953.

In a paper published two years ago, Biesel established general equations of movement resulting from the superposition of several wave trains [AMR **6,** Rev. 952]. Now the author evolves general equations of the partial clapotis. Graphs are attached to these equations enabling, after experimental measurements, knowledge of the reflection coefficients of a structure and the characteristic of the incident wave.

From author's summary by G. Supino, Italy

2098. **Milwitzky, B., Generalized theory for seaplane impact,** *NACA Rep.* 1103, 75 pp., 1952.

Supersedes papers reviewed in AMR **1,** Revs. 709, 1180.

Elasticity Theory

(See also Revs. 2090, 2094, 2095, 2096, 2113, 2114, 2116, 2118, 2119, 2120, 2121, 2131, 2133, 2143)

2099. Muskhelishvili, N. I., Some basic problems of the mathematical theory of elasticity, 3rd revised ed. (translated from Russian by Radok, J. R. M.), Groningen, Holland, P. Noordhoff, Ltd., 1953, xxxi + 704 pp. Fl 38.

Since Love's monumental treatise there has not appeared any text comparable in scope and achievement. It can now be stated that a new treatise on the subject of elasticity has been written. Muskhelishvili's treatise brings to the reader the most recent researches in this field, dating from his own original work in 1915 to 1949. During these years several hundred papers have appeared in Russian journals, utilizing his advances. This third and greatly enlarged edition of the original, which appeared in 1933, is prefaced by A. N. Krylov (who was well known for his contributions in applied mathematics) elaborating on the rich content of the subject matter. In his preface (in 1933) Krylov expressed his desire to see numerical and approximate methods in a future edition. Muskhelishvili's work has not, however, fulfilled this desire. But this, by far, does not limit the utility of the methods put forth.

This task has been adequately achieved in other texts, such as I. S. Sokolnikoff's, et al. The impact of Muskhelishvili's work is being observed presently in the non-Russian literature, where many authors are rediscovering his work for the first time, although many of his original papers appeared outside of Russia more than 20 years ago.

Although the development in this book is for isotropic bodies, other researchers in Russia, Great Britain, and the United States have extended Muskhelishvili's work to the anisotropic case.

This text presents the modern viewpoint of the theory of elasticity for the class of problems which can be considered as two-dimensional in character. It is composed of seven parts and 25 chapters with 150 subtopics. The first chapter develops the basic concepts of the analysis of stress in general for three dimensions and ends with the definition of plane stress.

Chap. II treats the fundamentals of the analysis of strain, starting with some general remarks, and discusses topics such as affine transformations, the strain quadric; it concludes with the determination of displacements from components of strain, and the equations of compatibility.

Chap. III derives the concepts of the fundamental law of the theory of elasticity (generalized Hooke's law) and then gives the derivation for isotropic bodies. Also, the fundamental boundary-value problems of static elasticity and the uniqueness of solution are lucidly given. Further topics such as Saint Venant's principle and the dynamic equations of an elastic body are discussed with comprehensive detail.

In part II of the book, chap. IV considers the basic equations of the plane theory of elasticity for an isotropic medium. Plane strain is covered in detail and also the deformation of a thin plate under forces acting in the plane of the plate. The chapter concludes with the basic equations of the plane theory and the reduction of these equations in the absence of body forces.

In chap. V the real contribution of Muskhelishvili's research is brought to light. This chapter is concerned with the stress function (Airy's stress function) and the complex representation of the solution to the biharmonic equation. From this is derived the complex representation of the stresses and displacements.

The results of the above stem from the original work of G. V. Kolosov dating back to 1904. These results were extended and further developed by the author from 1915 to the present. The basic problems of plane strain and plane stress are shown to reduce to the determination of two analytic functions satisfying a certain functional equation. Here is where the powerful tool of analytic function theory plays a dominant role. The structure of the functions is displayed for the simply and multiply connected domains, both finite or infinite in extent. The uniqueness of the solutions of these two problems is proved. The important practical problem of concentrated forces acting on the contour is treated in elegant fashion. Finally, the dependence of the state of stress on the elastic constants is exhibited.

The foregoing is developed by the author only for isotropic bodies, but the extensions of these formulas to the anisotropic case has been given by S. G. Lekhnitskiĭ, S. G. Michlin, and G. N. Savin in a series of papers dating back to 1935.

The concept of multivalued displacements and its allied idea of dislocations is covered in chap. VI, along with the elements of thermal stress. The treatment here is brief but to the point.

The fundamentals of conformal mapping constitute the main substance of chap. VII and cover several examples of the mapping of some special regions by rational functions onto the unit circle. By means of conformal mapping, the formulas of the plane theory of elasticity are transformed, along with the boundary conditions in the image region.

Part III contains the solution of several problems of the plane theory of elasticity by means of power series. Chaps. VIII and IX are contained therein, and many important practical examples are given for regions containing a circular boundary. Chap. X examines the details of the first fundamental problem for the circular ring. Chap. XI is devoted to the application of conformal mapping for simply connected regions. An example of the application of mapping onto a circular ring is given, as also the solution of the fundamental problems for a continuous ellipse (e.g., an elliptic ring bounded by confocal ellipses). Of interest is that the author points out that the solution to this problem given by A. Timpe by another method in 1923 is incorrect. The solution of this problem was also given recently by D. I. Sherman. Chap. XII is entitled "Fundamental properties of Cauchy integrals." Its content consists of the definition of Cauchy integrals, principle value, boundary values of Cauchy integrals, derivatives of these integrals, etc.

Boundary values of holomorphic (analytic) functions is the content of chap. XIII. It includes some general theorems, Harnack's theorem, and special formulas for the circle and half plane. It develops the formula of Schwarz for the solution of the Dirichlet and Neumann problems for these regions.

Part V relates to the application of Cauchy integrals to the solution of boundary-value problems of plane elasticity. Chap. XIV of this part of the text covers the reduction of the fundamental problems to functions equations and to Fredholm integral equations, and the existence theorems for them. Also treated are other applications of the integral equations for regions bounded by a single contour. Chap. XV deals with the solution of the basic problems for regions mapped onto a circle by rational functions, and the extension to approximate solutions for regions of general shape. There are several examples of practical interest given here in somewhat great detail. Other methods of solution are mentioned, among them the method of Schwarz, i.e., the algorithm of Schwarz. Among workers engaged in special and general methods of solution are G. N. Savin, D. I. Sherman, S. G. Michlin, and A. Y. Gorgidze. Chap. XVI treats the basic problems for the half plane and for semi-infinite regions. Chap. XVII discusses some general methods of solution of boundary-value problems and further generalization. Included are the integral equations of Michlin and of the author and applications to contours with corners. The method of D. I. Sherman for the solution of the first and second basic problems of elasticity is given in detail. This method lends itself well to effective numerical solutions, by replacing the kernel of the integral equation by a degenerate one. The mixed boundary-value problem is likewise treated by Sherman's method. It is mentioned that these methods find their extension to the anisotropic case and have been applied by Lekhnitski, Michlin, Savin, Sherman, and I. N. Vekua.

Part VI entails the solution of the boundary problems of the plane theory of elasticity by reduction to the problem of linear relation. The problem of linear relationship of the boundary values, one in which many problems in elasticity are solved by reduction to a single boundary problem of complex function theory, is dealt with in the author's "Singular integral equations," also translated by Radok, published by P. Noordhoff, 1953. Chap. XVIII develops the problem from first principles. In chap. XIX, the methods of solution are applied to the solution of the fundamental problems for the half plane and for the plane with straight cuts. Included is the solution of the mixed fundamental problem, the problem of the rigid stamp, and the technically important problem of contact (generalized plane problem of Hertz).

Chap. XX involves the solution of boundary-value problems for regions bounded by circles and for the infinite plane, cut along circular ares, and chap. XXI is concerned with the solution of the boundary problems for regions, mapped onto the circle by rational functions. Several examples are given, such as the infinite plane with an elliptic hole.

Part VII deals with extension, torsion, and bending of homogeneous and compound bars. In chap. XXII, the problem of Saint Venant is treated. The general solution of the torsion problem is given. Complex torsion functions, stress functions, and application of conformal mapping are among the topics discussed. Chap. XXIII treats the torsion of bars consisting of different materials. Chap. XXIV is concerned with the extension and bending of bars of different materials with uniform Poisson's ratio. Finally, chap. XXV delves into extension and bending for different Poisson ratios.

Appendix I is a concise and useful introduction to the concept of a tensor. Appendix 2 is on the determination of functions from their differentials in multiply connected regions, and Appendix 3 shows the details of the determination of a function of a complex variable from its real part.

There are an authors' index and references to 50 technical journals, mostly Russian, and not all readily available. The references to authors' papers number about 150, both Russian and non-Russian, and date back to the 19th century. There is also a subject index.

Needless to say, the content and style are brilliant. The book is recommended without qualifications to every student of the physical sciences with a mature mathematical background and who wishes to learn elasticity as it should be learned. Undoubtedly, another book of this scope and magnitude will not appear for at least another generation. The translator is to be highly commended for his task and for sticking so close to the original Russian version. Commendation likewise is extended to the publishers for enriching the field of technical literature.

J. J. Brandstatter, USA

2100. Peterson, R. E., Stress concentration design factors, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1953, x + 155 pp. $8.50.

This book represents a thorough presentation of information dealing with stress-concentration factors and design. In addition to presenting a wealth of information in graph form for

various types of stress concentration, an excellent review is also given of design relations based on theories of failure for both static and fatigue stresses. The book is well documented with numerous references to recent literature on the subject. Stress-concentration charts are presented for grooves and notches, shoulder fillets, holes in plates, and shafts. Various miscellaneous design elements are also discussed, including gear teeth, bolts and nuts, crane hooks, and many other elements. J. Marin, USA

2101. Timoshenko, S. P., Collected papers, New York, McGraw-Hill Book Co., Inc., 1954, xxv + 642 pp. $15.

This book contains a selection of the most important papers written by Timoshenko in English, German, and French during the period 1910–1950, reprinted in the original languages. The book starts with a 15-page biographical sketch, which also contains a list of titles of papers originally written in Russian in the period 1905–1917. These papers are not reprinted because the most significant parts were later republished by the author in other languages. There are three very long and important original papers: One of 50 pages in German on "Stability problem in the theory of elasticity"; another of 42 pages in German on "Beam vibrations"; and a third one in French of 132 pages on "The stability of elastic systems," covering trusses, I-beams, plates, and cylinders. The numerous shorter papers are on the subjects of the trigonometric method of beam-deflection calculation, the stability of plates, the torsional flexibility of crankshafts, the membrane analogy of beam bending; the bending of curved pipes of thin-walled rectangular cross section; the bending of beams of slight initial curvature; approximate methods in two-dimensional elasticity; stress concentrations; bimetal thermostats; suspension bridges; the bending and twisting of railroad rails by lateral forces; the calculation of gridworks of beams; and an experimental paper on applications of photoelasticity. Some of the subject matter of this book can be found in condensed form in the author's numerous other books on mechanics, but the bulk of its contents is to be found only in the original journals themselves.

It is an impressive work, a monument to the author of a 50-year period of great and influential activity. Besides that, it contains valuable and interesting information, in a well-printed and easily accessible form, which the contemporary reader otherwise would have difficulty finding in numerous volumes in libraries.

J. P. Den Hartog, USA

2102. Wang, C.-T., Applied elasticity, New York, London, Toronto, McGraw-Hill Book Co., Inc., 1953, ix + 357 pp. $8.

This textbook covers in a very lucid and well-organized and at the same time concise manner a variety of topics in applied elasticity. Special emphasis is put on approximate solutions by the use of finite difference and relaxation methods.

The first three chapters (41 pp.) introduce the reader to the theoretical analysis of stress and strain in two and three dimensions, the compatibility equations, generalized Hooke's law, and strain energy.

Chap. 4 (35 pp.) deals with the Airy stress functions in Cartesian and polar coordinates. Several problems illustrating the use of the stress functions are solved.

Chap. 5 (29 pp.) gives the principles of Saint Venant's torsion for prismatic bars and shafts of variable diameter, the membrane analogy, and Prandtl's stress function. Also problems of torsion of thin-walled tubes of multicell cross sections are solved.

Chap. 6 (38 pp.) presents the finite difference and relaxation methods in a very clear manner. Chap. 7 (27 pp.) explains the energy principles and the Castigliano, Rayleigh-Ritz, Galerkin, and Biezono-Koch methods.

Chap. 8 (38 pp.) expounds the principles of analysis of problems of torsion and of plane stress and strain by the methods of complex variables. Many solved problems demonstrate the application of this method.

Chap. 9 (31 pp.) treats the bending and compression of prismatic bars and the application of the theory of elastic stability to beams of variable and narrow cross sections.

Chap. 10 (36 pp.) illustrates the application of the methods of finite differences and of Rayleigh to the solution of various problems in elastic stability.

Chap. 11 (34 pp.) contains the derivations of the equations of the deflection surface of thin rectangular and circular plates with various boundary conditions and a few problems in buckling of rectangular plates.

Chap. 12 (34 pp.). After a review of basic principles of differential geometry, the general and the membrane theories of shells are presented. Problems dealing with symmetrical and unsymmetrical loading conditions are solved.

Throughout this book the theoretical part is kept to a minimum, but the various methods of solutions of problems are well presented. It is a valuable addition to technical literature and will allow students and engineers to become acquainted with various methods used in applied elasticity in the shortest time.

W. Ornstein, USA

2103. Reissner, E., On finite twisting and bending of circular ring sector plates and shallow helicoidal shells, *Quart. appl. Math.* **11,** 4, 473–483, Jan. 1954.

A thin circular ring sector under the action of two equal and opposite forces perpendicular to the plane of the plate, along the axis through the center of the ring is considered. The differential equations in terms of deflection and Airy's stress function are given and solved. This method makes it possible to analyze the nonlinear effects in a relatively simple manner.

The problem of the effect of a moment about the axis of the ring is also considered and solved. This solution is combined with the first in order to solve the problem of combined twisting and bending.

The functions occurring in the load displacement relations and in the stress equations are calculated and tabulated.

The equations can be used to solve problems relating to the stresses and deflections of closely coiled helical springs with a flat cross section. It is possible to consider the influence of initial pitch on the stresses and deformations.

R. M. Wingren, USA

2104. Tiffen, R., Generalized plane stress problems in infinite elastic strips, *Quart. J. Mech. appl. Math.* **6,** part 3, 344–369, Sept. 1953.

Author obtains solutions in terms of complex potentials of generalized plane stress problems for infinite strips of isotropic elastic material. He treats the following types: (a) Assigned boundary stresses including concentrated loads on both straight boundaries, (b) assigned displacements on both boundaries, (c) assigned stresses on one boundary and given displacements on the other, (d) interior isolated loads with both boundaries stress-free, or both displacement-free, or one stress-free and the other displacement-free.

In most cases the required representation of the stress and displacement potentials is by Fourier integrals, many of which require careful modifications to insure convergence. As an example, an isolated boundary force applied along one edge is not treated as a limit solution of an intense Gaussian distribution of normal edge pressure. Author contends that most previous results employing integral representations lead to infinite displace-

ments at infinity and that an appropriate synthesis of potentials will relieve this situation in the case of isolated boundary forces.
D. L. Holl, USA

2105. Luxenberg, H., Torsion of anisotropic elastic cylinders by forces applied on the lateral surface, *J. Res. nat. Bur. Stands.* **50,** 5, 263–276, May 1953.

The Saint Venant theory solves the torsion problem of an isotropic or anisotropic rod of uniform section for the relaxed end conditions of pure couples and with the lateral surface free of stress. This paper considers the anisotropic rod (13 elastic constants) which is clamped at one end and is twisted by forces applied uniformly along the lateral surface. The problem is attacked by assuming the final stress system is the sum of three systems: a plane strain system, a modified torsion system for lateral surface forces and relaxed conditions at the clamped end, and a linear stress system which requires the resulting bending couples and tension to vanish on the end sections. The equilibrium equations and compatibility relations require that the plane stress function $\psi(x, y)$ and the modified torsion function $\phi(x, y)$ simultaneously satisfy two partial differential equations involving second-order derivatives of ϕ and fourth-order derivatives of ψ. However, the boundary conditions are such that the boundary-value problems are separable and the torsion problem is reducible to a Neumann problem. With this problem completed, the stress function ψ satisfies a soluble fourth-order equation. The author shows the degenerate case of an isotropic rod and also solves the case of an anisotropic elliptic rod where the results become polynomials in x, y.
D. L. Holl, USA

2106. Reissner, E., On finite torsion of cylindrical shells, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 49–51, Apr. 1953.

Author considers the problem of finite torsion of hollow beams composed of two shallow cylindrical and symmetrical shells. (The plane passing through the two lines along which the two shells are joined consequently is a plane of symmetry for the cross section of the beam in its unstressed state.) It is shown that, for this class of cross section, the problem of finite torsion may be solved explicitly by means of the differential equations for finite deflections of shallow shells, which have been given by Marguerre [Proc. Fifth int. Congr. appl. Mech., 93–101, 1948]. One or two simple illustrations would certainly have clarified this interesting paper.
C. B. Biezeno, Holland

Experimental Stress Analysis

(See also Revs. 2101, 2142, 2170, 2362)

2107. Heywood, R. B., Designing by photoelasticity, London, Chapman & Hall, Ltd., 1952, xvi + 414 pp. 65s.

This book takes photoelasticity out of the laboratories devoted to pure research and into laboratories devoted to applied research. It makes this method of experimental stress analysis available to the engineer who is interested in design.

The book contains a discussion of the basic equipment and techniques required for the solution of both two- and three-dimensional problems, a discussion of photoelastic materials with recommendations for their preparation and use, the interpretation of experimental results, and the transfer of stress in the model to stress in the prototype.

Also included is an excellent presentation of the important subject of stress concentration, including a discussion of the effect of multiple notches. The book reviews and correlates much of the information available in the literature and presents these data in such a manner that they may be readily assimilated and used by the designing engineer.

The improvement of design features and the use of the photoelastic technique to select the best of several design treatments are discussed in some detail. A bibliography of about 800 references is included in the appendix.

In the opinion of this reviewer, this is probably the most useful work available, in this field, for use by the design engineer.
R. H. Trathen, USA

2108. Szántó, I., Novel x-ray diffraction technique for measuring internal stresses in metals, *Acta Techn. Hung. Budapest* **7,** 1–2, 165–185, 1953.

Widespread use of current radiographic stress inspection methods has been impeded chiefly by the difficulty of meeting the rather particular requirements of focusing on which the accuracy of measurements has depended. The new technique simplifies measurement by two solutions differing in principle; their common feature is that stress determination does not necessitate an accurate knowledge of the distance between the surface of the object and the plane of registration.

One of the solutions is to obtain an evaluation mathematically from the relative position of both lines of the characteristic K_α-doublet radiation applied in registration. This method demands a high sensitivity of registration, therefore such accurate measurement of reflections is only possible with equipment provided with an electronic counter; it can thus be made automatic.

The second method is based upon direct measurement of reflection angles. The new camera here presented has made attainable, in testing steel, a degree of precision identical with that of the results of the current technique of radiography, but by a much simpler measuring procedure. A detailed evaluation of a series of tests carried out by means of the new technique completes this paper.
From author's summary by F. Wever, Germany

2109. Hiltscher, R., Photoelastic apparatus for research and industrial laboratories (in German), *Trans. Instrum. Measurements Conf., Stockholm,* 1952, 7 pp.

A portable photoelastic apparatus is described which works with diffuse light. Contrary to the usual optical method, this is handier and requires less space for the same conductivity.
From author's summary

2110. Clough, W. R., Shank, M. E., and Zaid, M., The behavior of SR-4 wire resistance strain gages on certain materials in the presence of hydrostatic pressure, *Proc. Soc. exp. Stress Anal.* **10,** 2, 167–176, 1952.

Need for experimentally determined correction factors is documented by tests on simple SR-4 gaged specimens subjected to hydrostatic pressure. Right circular cylinders were gaged on ends and cylinder, and hollow cylinders were gaged internally.

Summation of the effects, differential change in gage factor, differences in pressure effects on nonidentical objects, differences and defects in gage application to base material may be much greater than effect being compensated for by using dummy gage. Correction factors may be determined by subjecting entire structure with active and dummy gages to hydrostatic pressure. In general, a different correction factor will be observable for each gage. Gages with nonlinear response were discarded. A devised method for determining accuracy of linear correction factors when gages are used on nonlinear materials shows that linear correction factors are satisfactory on gray cast iron and nodular cast iron. Necessary equations, data, and graphs are presented.
G. R. Carlson, USA

2111. **Rickert, W. K., Flight test applications of strain gages** (in French and English), *AGARD Memo.* AG2/M1, Rome AGARD Conf., Dec. 12–19, 1952, 27–53.

2112. **Abbott, I. H., Some application of strain gages in aeronautical research** (in French and English), *AGARD Memo.* AG2/M1, Rome AGARD Conf., Dec. 12–19, 1952, 3–26.

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 2089, 2096, 2100, 2101, 2103)

2113. **Truesdell, C., A new chapter in the theory of the elastica,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 52–55, Apr. 1953.

Author considers the problem of computing the shape of an unloaded cantilever such that, when subjected to a uniform normal load p (per unit length) along its entire length, it shall lie upon a prescribed plane curve. On the basis of a simple theorem on static equivalence of plane distributions of forces, he arrives at a general expression for the change of curvature of his beam due to the application of the load. Integrating, while confining himself to inextensional deformations, author finds that the change in slope, at any point P, from the unloaded to the loaded shape is proportional to the polar moment of inertia, about an axis through the free end, of the portion of the beam extending from its fixed end to point P. The actual free shape is then expressed as a quadrature. The paper closes with an explicit solution for the case where the loaded beam is to be straight.

H. Deresiewicz, USA

2114. **Bridge, E. K., A machine for calculating electrically the bending moment and shear loading effect of moving loads on varying spans,** *Publ. int. Assn. Bridge struct. Engng.* **13,** 75–85, 1953.

The Bridge Office of the Southern Region of British Railways built an electrical analog computer for determining the equivalent uniform load for a simple beam loaded with moving concentrated loads. The instrument accommodates up to 22 loads varying from 0.05 to 31.0 tons in any desirable arrangement on spans up to 150 ft, and is capable of evaluating the equivalent uniform load both for maximum moment and shear. The underlying principles, the make-up, and the operation of the instrument are described.

I. M. Viest, USA

2115. **Engel, H. L., and Goodier, J. N., Measurements of torsional stiffness changes and instability due to tension, compression, and bending,** *J. appl. Mech.* **20,** 4, 553–560, Dec. 1953.

The tests verify very precisely both the linear relation between torque and twist on the one hand and between apparent torsional rigidity (torque:twist) and applied tensile load or bending moment on the other hand. Nonlinear relations result in the case of restrained warping and, if one considers second-order effects, of a bar of angle section under combined torsion and bending. Also treated are buckling phenomena of the same bar under certain load conditions, i.e., single end load and pure bending moment, respectively.

F. M. Mueller, USA

2116. **Pivovarov, A. M., Tangential stress concentration in prismatic bars in torsion** (in Russian), *Prikl. Mat. Mekh.* **17,** 2, 253–259, Mar.-Apr. 1953.

Author considers cross sections with cutaways. The cutaways are called penetrating angles. Formulas containing torsion stress function, such that it satisfies Poisson's equation, are used. Author's method is used for obtaining derivative of stress function with respect to interior normal for determining stresses at a point on the contour. Thus, obtained formula contains two double integrals. First integral contains harmonic function valid in the region except for a specified contour point where it is determined by position vector and the angle between this vector and internal normal. Second integral contains harmonic function which, on the contour, consists of series. This integral has coefficients which depend on the number of symmetrical contour points and angle value. Author's examples include: Square section with zero-angle cutaway; angle section (with right-angle cutaway); and arbitrary circular sector.

V. A. Valey, USA

2117. **Barrett, A. J., Unsymmetrical bending and bending combined with axial loading of a beam of rectangular cross section into the plastic range,** *J. roy. aero. Soc.* **57,** 512, 503–509, Aug. 1953.

The bending moment in the plastic range for rectangular cross section is computed so that the maximum fiber stress is equal to a certain stress beyond the proportional limit (0.5% proof stress for light alloys). The computation starts from an assumed direction of neutral axis; the stress-strain curve is replaced by a mathematical expression. Two cases are considered: unsymmetrical bending, and symmetrical bending combined with axial loading.

F. Stüssi, Switzerland

2118. **Sengupta, A. M., The effect of two equal circular holes on the stress distribution in a beam under uniform bending moment,** *Bull. Calcutta math. Soc.* **45,** 2, 65–68, June 1953.

Author derives solution for influence on stress distribution of two equal circular holes with centers at neutral axis of deep rectangular beam under uniform bending moment, using a bipolar stress and coordinate system. Numerical results regarding the circumferential stresses at the circular boundaries are given for circles of which the ratio of the radius and the distance between centers is approximately 3/8. The maximum circumferential stress for this case is found to be about 5% less than that for a beam with a single hole, and the location of this stress is displaced only very slightly on the boundary.

P. Seide, USA

2119. **Das, S. C., On the stresses due to a small spherical inclusion in a uniform beam under constant bending moment,** *Bull. Calcutta math. Soc.* **45,** 2, 55–63, June 1953.

Analysis is given of the effect on stress distribution of an isotropic spherical inclusion in a uniform isotropic beam under constant bending moment, the dimensions of the beam being very large compared to inclusion radius. Numerical values of maximum components of stress at inclusion surface are given for the cases of a rigid inclusion and an inclusion having Young's modulus $^1/_4$ that of surrounding material. Poisson's ratio is 1/4.

P. Seide, USA

2120. **Starnberg, W., The torsion of metallic bars for a general law of yielding, considering also the fracture conditions** (in German), *Öst. Ing.-Arch.* **7,** 4, 299–309, 1953.

This is a very valuable investigation in which the author attempts to discuss, using as an example the torsion of prismatic bars, the state of stress after postulating a general stress-strain curve for the tensile test $\sigma_z = f(\epsilon)$, which may differ from the curve for the compression test $\sigma_d = g(\epsilon)$, and either for ductile metals or brittle materials. In both types of materials he furthermore considers certain conditions at fracture which may be either failures of a brittle character or shear failures. He designates the stresses at fracture by σ_Z or σ_D, the capital subscript letters Z (German Zug, tension) and D (German Druck, axial compression) referring to the point of fracture, while the lower-case subscripts in σ_z and σ_d

refer to general yielding or to flow stresses in tension or compression, respectively. In order to characterize the behavior of a given material he introduces, following a suggestion by A. Leon, a variable parameter: $c = \sigma_D/\sigma_Z$.

Whereas Leon intended to define with this parameter only the ratio of the fracture stresses in axial compression and tension, and to express herewith the degree of brittleness ($c = 1$, characterizing ductile behavior in steels, aluminum; $c = 3$–5, brittle behavior of cast iron; $c = 10$–15, that of concrete or natural rocks). C. Torre has recently generalized this parameter c by assuming that it may continuously vary for one and the same material if one postulates a stress-strain diagram which differs in the tensile from the one in the axial-compression test. If both diagrams coincide with each other, the value of $c = \sigma_d/\sigma_z$ remains constant at $c = 1$ for the entire interval from the beginning of yielding to fracture (as in mild steels), while in certain metals behaving still in ductile manner one finds cases when $1 \leqq c \leqq 2$–3. Torre thus defines the parameter c by $c = \sigma_d/\sigma_z$, letting $\sigma_d = \sigma_q$ represent the flow stress in compression and $\sigma_z = \sigma_s$ in tension. A variable c according to $1 \leqq c \leqq 2$–3 therefore refers to one and the same material. Author, in following ideas published by Torre [AMR **4**, Rev. 1165; **3**, Rev. 1088], makes use of a general "surface of yielding" represented in the rectangular coordinates σ_1, σ_2, σ_3 of the principal stresses, which he assumes, according to Leon, to be a paraboloid of revolution

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 + 2(c - 1)\sigma_z(\sigma_1 + \sigma_2 + \sigma_3) = 2c\sigma_{z^2}$$

where $1 \leqq c \leqq 2$–3, having its axis coinciding with the space diagonal $\sigma_1 = \sigma_2 = \sigma_3$. For $c = 1$, this paraboloid becomes the cylinder of the theory of Mises-Hencky. Subsequently, he develops the theory of plastic torsion, introducing the plastic stress function $F(x, y)$ of the referee

$$(\partial F/\partial x)^2 + (\partial F/\partial y)^2 = c/3\sigma_z^2$$

computes the twisting moment, and compares the values of it with various results on fracture tests under torsion and finds good agreement. A. Nadai, USA

2121. De Schwarz, M. J., Note on the torsion of a prism (in Italian), *Cons. naz. Ricer.* no. 371, 4 pp., 1953.

Author shows that the twisting of a hollow shaft whose internal and external boundaries are concentric, similar, regular polygons produces an infinite stress (mathematically) at the internal reentrant angles and that this holds for polygons of any number of sides. G. W. Housner, USA

2122. Markl, A. R. C., Piping flexibility analysis, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-51, 37 pp.

This work represents a study of a "Task force on flexibility" charged with reformulating a section of the Code for Pressure Piping under ASA committee B31.1. A review is given of the scientific background underlying the proposed rules, together with their justification and explanation. The paper attempts to provide design rules which are both sufficiently accurate and simple enough for practical engineering use. An excellent bibliography is included.

The following principal topics are treated at length: (1) Flexibility factors for pipe bends and corrugated tubes. If h is defined as equal to tR/r^2—where t, R, and r, are pipe-wall thicknesses, radius of center line of bend, and mean pipe radius, respectively—then the flexibility factor is given as $1.65/h$ for bends without flanges at their ends. For 90° elbows, flanged at one or both ends, flexibility factors are given, respectively, as $1.65/h^{5/6}$ and $1.65/h^{2/3}$. Miter and creased bends, corrugated pipe, and other components are also considered.

(2) Stress intensification factors. The stress factor is defined as the ratio of bending moment causing failure in a given number of cycles in a straight pipe to that producing failure in the same number of cycles in a part under consideration which has the same nominal dimensions. This definition results in different stress factors from those calculated or those determined from strain measurements. A stress factor of $0.9/h^{2/3}$ applies to most bends and elbows. The allowable stress is given as a function of the number of temperature cycles estimated during the expected life of the system. Stress factors are also suggested for miter bends, tees, corrugated pipe, and various other types of components. (3) Reactions. The reactions of a piping system on its supports are treated generally but leaves to the judgment of the engineer what method is most appropriate for any given situation. Appendixes include the text of the proposed rule changes. The proposed rules do not make mandatory the use of specific stress and flexibility factors. I. Vigness, USA

2123. Vissat, P. L., and Del Buono, A. J., In-plane bending properties of welding elbows, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-70, 24 pp.

An experimental stress analysis of 12 commercial 180° short radius welding elbows from 5-in. to 8-in. nominal pipe size, an α^1 (= nominal pipe size/2 × bend radius) of $1/2$ and $1/3$, and varying in flexibility factor λ[= pipe wall thickness × mean pipe radius/-(bend radius)^2] from 0.07 to 0.74.

Since thin-walled curved tubes are known to have stresses and deflections different from bars with the same moment of inertia, section modulus, and radius of curvature, the results are presented in the form of ratios of measured values to those calculated for this equivalent curved bar. Values are given for K the flexibility or deflection ratio, β_1 the stress ratio for longitudinal stress at the outer surface, β_t the transverse stress at the outer surface, and β_{10} the longitudinal stress in a surface where the transverse stress is zero. These stresses are measured in the plane of symmetry of the elbows and around the circumference of the pipe.

Comparison with earlier theoretical treatments for $\alpha^1 < 1/10$ indicates good agreement in K values but poor agreement in β values as anticipated by the earlier authors. Empirical relations for K and β for the range of λ covered are given in the general form A/λ^n, where A and n are constants.

The effect of flanges on K and β is found to be small.

A discussion of stress intensification at the inner surface of the pipe indicates 16% larger β_t values than at outer surface, but only few experimental data are available.

Authors plan to extend this very thorough study with tests on the effects of internal pressure. E. G. Chilton, USA

2124. Morrison, J. A., Closure waves in helical compression springs with inelastic coil impact, *Quart. appl. Math.* **11,** 4, 457–471, Jan. 1954.

Paper deals with problem of spring surges taking coil closure into account. This may occur in many cases of compression springs subject to impact. Inelastic coil-on-coil impact conditions are assumed. Simple theory of spring surges is adopted. Basic theory of coil closure with inelastic impact conditions has been given by E. H. Lee.

Spring is initially at rest and unstrained with one end fixed, and impact end is given an impulsive velocity, either constant or decelerated at constant rate. Mass attached to impact end is also considered. Conditions are obtained for which partial or complete closure of spring occurs.

From author's summary by S. Sjöström, Sweden

2125. **Downham, E., Some preliminary model experiments on the whirling of shafts,** *Aero. Res. Counc. Lond. Rep. Mem.* 2768, 20 pp., June 1950, published 1953.

Experimental work is now being done to establish a basis for the solution of whirling problems on turbine and contrarotating shaft systems in the design stage. This report is concerned primarily with the degree of accuracy to be expected from experiments on models.

In the experiments here described, results are obtained for a simple cantilever system, which are in close agreement with theory. With more complicated systems the error is somewhat greater owing to practical effects not covered by theory, though still acceptable for most design purposes.

From author's summary

2126. **Otto, P., Rope creep on sheaves** (in Dutch), *Ingenieur* 65, 31, W.139–W.146, July 1953.

The forces in a cable before and behind a driven or driving sheave being different, "creep" of cable over part of sheave must occur owing to variation of elongation of cable in contact with sheave. Paper gives theoretical analysis of cable force distribution, amount of creep, and frictional energy accompanying creep. Results are compared with previously published ones, showing some improvements in present analysis; a numerical example of application is given. E. J. Plantema, Holland

Plates, Disks, Shells, Membranes

(See also Revs. 2100, 2101, 2103, 2106, 2138, 2148)

2127. **S. Schwaigerer, The analysis of flange connections for containers and piping systems** (in German), *ZVDI* **96,** 1, 7–12, 1954.

Author assumes that at the juncture of flange and tapered hub there develops a plastic hinge. Making numerous further rather bold (and in reviewer's opinion partly unjustified) assumptions, he arrives at a simple formula which relates bolt moment, yield stress, and safety factor to dimensions of flange and hub.

G. Horvay, USA

2128. **Lardy, P., On a new method of resolution for clamped rectangular plates** (in French), *Publ. int. Assn. Bridge struct. Engng.* **13,** 197–220, 1953.

Paper uses normal functions for the vibration of doubly clamped beams to form double-series solutions for problems of the deflection of grids of beams and plates under transverse pressure. Deflection and loading are both assumed expanded in series of normal functions. Equation of the coefficients of similar terms follows after a subsidiary expansion of second derivatives of normal functions in terms of those functions themselves. Resulting algebraic equations are solved by successive approximation. Tables of coefficients required for the method and numerical examples showing quite rapid convergence are given in the paper.

W. S. Hemp, England

2129. **Bogunović, V., On the bending of rectangular plates with one free edge** (in Serbian), Beograd, Zbornika Gratchevinskog Fakulteta, 1952–1953, Ph.D. thesis, 186 pp.

This paper presents deflection solutions to plates having one free edge with remaining edges in accordance with the following schedule: (1) Simply supported along the other three edges; (2) the edge opposite the free edge fixed and the other two simply supported; (3) the edge opposite the free edge simply supported and the other two fixed; and (4) all three edges fixed.

Bending in case (1) is due to a single concentrated load applied at an arbitrary point, while in cases (2), (3), and (4) the plates are uniformly loaded, or a concentrated load is applied at the middle of the free edge. Author claims the solution of case (1) may be extended to any other loading by simple integration.

Superposition is used as a basic procedure to obtain deflections by adding to w_1 the known deflection of a plate supported simply along all edges, and to w_2 the deflection resulting from application of couples uniformly distributed along the free edge. This is extended to cases actually having distributed couples along the fixed edges. Couple intensities are expressed by trigonometric series and the coefficients and moments are determined by equalizing the slope of the elastic surface of the plates along the fixed edges.

From author's summary by J. P. Vidosic, USA

2130. **Sheremet'ev, M. P., Bending of thin plates with reinforced boundaries** (in Russian), *Ukrain. mat. Zh.* **5,** 58–79, 1953.

Paper gives a formulation of the problem of small transverse deflections of a thin elastic plate reinforced along the edge by a ring whose thickness and rigidity differ from those of the plate. The middle surfaces of the plate and the ring, in the undeformed state, lie in the (x,y)-plane and the cylindrical edge of the plate is welded onto the ring. The plate so reinforced is then deformed by forces and moments distributed along its edge. The state of stress in the interior of the homogeneous and isotropic plate is thus determined by two analytic functions $\varphi_i(z)$ of the complex variable $z = x + iy$, which satisfy certain conditions along the contour of the weld, depending on the nature of the reinforcing ring. If the ring is so thin that it behaves like an inextensible curved rod in the Kirchhoff-Clebsch theory of thin rods, it is possible to deduce the appropriate boundary conditions. The author calculates the functions $\varphi_i(z)$ for an infinite plate with a circular hole when the plate is deformed by the application of constant bending and twisting moments at a great distance from the whole and when the ring is free of external loads.

I. S. Sokolnikoff, USA

2131. **Guzmán, A. M., and Luisoni, C. J., Elasticity and plasticity of skew plates** (in Spanish), *Publ. Fac. Cienc. Fisicomat., Univ. nac. Eva Peron* (2) **4,** 5, Separ. 1, Rev. Dept. Constr., 452–493, June 1953.

In view of the increasing structural applications of skew plates, authors carry out an analysis of the same in their elastic aspects, as well as in the plastic. In the elastic range, it is emphasized that most of the published papers preferably employ the finite-differences method, which shows its inconvenience in its lack of general results and of a high number of unknowns involved without assuring a satisfactory approximation, mainly if clamped edges exist; dealing with the analytical solutions, the differential equation's general integral has not yet been given and only rather unsatisfactory polynomial expressions have been tried. The authors give a new solution with more adequate polynomials, making use of oblique coordinates and employing Galerkin's variational method to find the polynomial coefficients. The check of said solution is obtained by taking as a limit case a rectangular plate, the agreement being very satisfactory. Three approximations are studied for the clamped plate.

In the plastic range, authors try to foretell the ultimate load in a simple way. They also support the Ingerslev-Johansen theory of lines of fracture, discuss a condition of minimum load, compare the plastic studies of continuous frames with those of plane plates, making a generalization; tests were carried out on small specimens with concentrated load at the center to check the concordance between the theoretical and experimental ultimate loads, finding good agreement between the theoretical values and those measured.

From authors' summary by P. Bielkowicz, USA

2132. Grasshoff, H., Sole pressure distribution under radial symmetrically loaded circular foundations (in German), *Bautechnik* **30,** 12, 352–358, Dec. 1953.

A numerical solution is given of the problem of bending of a circular plate on an ideal elastic foundation (for any radial variation of the modulus of the foundation) and on an elastic semi-infinite solid. Although the paper does not refer to the integral equation of the problem—such reference is not necessary for the understanding of the author's method of computation—the solution consists in effect in substituting for this equation the set of linear algebraic equations using a specified rule of numerical integration. The coefficients in the set of algebraic equations in the case of a uniformly thick plate are tabulated for a given spacing of increments along the radius. D. Radenković, Yugoslavia

2133. Heisler, M. P., Transient thermal stresses in slabs and circular pressure vessels, *J. appl. Mech.* **20,** 2, 261–269, June 1953.

First problems considered involve one-dimensional heat flow through thickness of slab having one face insulated and other face exposed to an ambient medium. A finite surface heat-transfer resistance is assumed. Beginning with solution for unit step in temperature of ambient medium, author uses Duhamel integral to obtain solution for linear time variation of ambient temperature. Temperature distribution in latter case is shown to be linearly related, at any instant, to that resulting from heating by uniform internal generation in slab, starting from thermal equilibrium. Stresses are determined for foregoing temperature distributions, assuming edges of slab are restrained against rotation but free to translate in plane of slab. Since extreme stresses occur at exposed surface, solutions are evaluated at this location only. Through use of dimensionless temperature, stress, and time variables, author makes extensive graphical presentation of results with only a single parameter (the Nusselt number). A numerical example illustrates determination of maximum permissible cooling rate without exceeding a specified stress.

In latter portion of paper a parallel development is given for radial heat flow through a hollow cylinder with outer surface insulated and inner surface exposed to an ambient medium. Formulas here involve very formidable series with complicated combinations of Bessel functions. Author notes these formulas "pose difficult problems in evaluation." Reviewer feels this is an understatement and that direct numerical solution of differential equation might be more practical.

Reviewer believes paper represents a substantial contribution. Results for slab are in convenient form and should be very useful in many practical applications. R. E. Newton, USA

Buckling Problems

(See also Revs. 2101, 2115)

2134. Masur, E. F., Lower and upper bounds to the ultimate loads of buckled redundant trusses, *Quart. appl. Math.* **11,** 4, 385–392, Jan. 1954.

Paper presents general equations between external and internal forces in statically indeterminate prestressed trusses during buckling. As buckling proceeds, the corresponding external loads approach limiting values. The solution of the equations presents formidable numerical obstacles. Author derives an easier way of estimating the ultimate load by two theorems establishing lower and upper bounds to the ultimate load. Of these, the lower bound permits an approach to the exact value from below within any desired degree of accuracy. Elastic behavior is assumed.

S. E. Kindem, Norway

2135. Salvadori, M. G., Lateral buckling of I beams under thrust and unequal end moments, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 291, 24 pp., Oct. 1953.

Interaction curves are derived for I-beams under thrust and unequal end moments by the Rayleigh-Ritz method, expanding the lateral deflection and the angular rotation into Fourier series. It is shown that the interaction curves may be used to determine lower bounds for thrust and end moments of continuous beams. Some examples of calculation are given.

P. P. Bijlaard, USA

2136. Deutsch, E., Simple calculation of the buckling load for straight bars with any variable moment of inertia (in German), *Stahlbau* **22,** 10, 224–226, Oct. 1953.

Centrally loaded slender (Euler) columns with variable cross sections such that the distributions of moment of inertia are either rectilinear or parabolic are investigated for four ideal sets of end conditions: One end fixed, the other free; both ends hinged; one end fixed, the other hinged; and both ends fixed. Simplicity of computation is accomplished by describing elastic curves by polynomials, the resulting error of approximation being indicated as less than 1%. Numerical values of buckling constants are tabulated for several ratios of maximum to minimum moment of inertia for each set of end conditions. It appears that constant cross sections are most favorable with high degrees of end fixity, but variable cross sections are advantageous with small end fixity. A. D. Topping, USA

2137. Hunter, T. A., Experimental investigation of column action after buckling, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 186–190, Apr. 1953.

It is the purpose of this investigation to determine experimentally the action of mild-steel columns after they have buckled, in order to determine how much load they will actually support and thus how much load must be shifted to other members. The range of slenderness ratios has been chosen from 20 to 160 to cover the usual useful range for steel. In addition, since one of the common methods of analyzing frameworks is by the energy method, it is intended to investigate the amount of energy dissipated during the large buckling and also to examine the action of the column as the load is removed. From author's summary

2138. Slankard, R. C., and Nash, W. A., Tests of the elastic stability of a ring-stiffened cylindrical shell, model BR-5 (λ = 1.705), subjected to hydrostatic pressure, *David W. Taylor Mod. Basin Rep.* 822, 41 pp., May 1953.

This model was the second in a series of models to be used in order to develop a more comprehensive understanding of the elastic stability phenomenon and was also intended to be a duplicate of the first one [*TMB* Restricted Rep. C-439, March 1953] to check on repeatability of test results.

Instrumentation and procedures are thoroughly described. The out-of-roundness was measured by means of an automatic recording deflectometer. Test results are compared with different theories.

Model exhibited a marked initial out-of-roundness. The elastic behavior was nonlinear at all pressures. Deformation pattern prior to buckling was mainly an exaggeration of the initial distortion of the shell. Buckling pressure was considerably less than that predicted by the theories of von Mises or Salerno and Levine. Authors attribute the discrepancy partly to the initial out-of-roundness of the model and residual welding stresses. However, the markedly greater out-of-roundness of the first model as compared with that of this model does not seem to have produced a corresponding decrease in buckling pressure.

E. Steneroth, Sweden

2139. **Hemp, W. S., and Griffin, K. H., The buckling in compression of panels with square top-hat section stringers,** *Aero. Res. Counc. Lond. Rep. Mem.* no. 2635, 14 pp., June 1949, published 1953.

A simplified panel model is described. The mode of buckling is assumed. Buckling stress is calculated by splitting the panel into a number of flat plates and treating these by the ordinary plate theory. During buckling, the square stringer corners are assumed to remain fixed in space and the right angles at these corners are conserved. Use of boundary conditions between the plates leads to a relation between the buckling stress and the variables of the panel geometry. The calculated results are compared with two sets of experimental work. The effect of initial panel irregularities on the experimental determination of buckling stresses is shown in an appendix. T. H. Lin, USA

Structures

(See also Revs. 2085, 2101, 2134, 2139, 2155, 2339)

2140. **Benscoter, S. U., and MacNeal, R. H., Analysis of straight multicell wings on Cal-Tech analog computer,** *NACA TN* 3113, 79 pp., Jan. 1954.

A survey of numerical results obtained from analog computers. Computer circuits are designed to simulate wing as equivalent plates. Computer results are compared to results of beam theory. Numerical results tend to indicate good agreement with beam theory for normal stresses and deflections due to bending loads, poor agreement for shear stresses. Computer results indicated that total moments and shears on various cross sections did not satisfy static equilibrium and correction factors were introduced into the circuits to correct this. Reviewer feels that in view of this fact the estimate of computer error given by authors is meaningless. M. A. Brull, USA

2141. **MacNeal, R. H., and Benscoter, S. U., Analysis of multicell delta wings on Cal-Tech analog computer,** *NACA TN* 3114, 84 pp., Dec. 1953.

Solutions for stresses and deflections in multicell delta wings are obtained from analog computers. Solutions are based on same assumptions as *TN* 3113 by same authors (see preceding review) with additional approximations concerning behavior of leading-edge spar and triangular panels. Results indicate that leading-edge spar has considerable influence in distribution of spanwise leading moments and that chordwise bending is of enough importance to affect stress distribution significantly. The same criticism made of *TN* 3113 applies to authors' estimate of errors. M. A. Brull, USA

2142. **Stein, M., Anderson, J. E., and Hedgepeth, J. M., Deflection and stress analysis of thin solid wings of arbitrary plan form with particular reference to delta wings,** *NACA Rep.* 1131, 20 pp., 1953. (Supersedes AMR 5, Rev. 2816.)

2143. **Besseling, J. F., and Floor, W. K. G., Torsional strength and stiffness tests of wing leading edges,** *Nat. LuchtLab. Amsterdam Rep.* S.421, 44 pp., June 1953.

Torsion tests on wing structures were carried out in order to obtain the desired information about strength and stiffness. The torsion of the test specimen was measured at increasing and at decreasing load in several loading cycles with successively increasing maximum load. In the last cycle the ultimate load sustained by the structure was determined. Details of the buckles occurring in the skin, especially in the nose region, were photographed at several stages of development. The prebuckling torsional stiffness proved to be in good agreement with the Batho-Bredt formula for thin-walled tubes loaded in torsion.

An empirical formula was derived for calculating the ultimate shear stress in the skin of wing leading edges manufactured from 24S-T Alclad. The main parameters governing the ultimate stress are the nose-radius-to-rib-spacing ratio and the skin-thickness-to-nose-radius ratio.

The influence of the closing web position is rather small.

From authors' summary

2144. **Braham, W. E., The trend of complete aircraft and guided-missile structures toward reinforced plastics,** *Aero. Engng.* **12,** 9, 37–40, Sept. 1953.

2145. **Negoro, S., On a method of solving torsion and bending problems of continuous panel structures,** *Rep. Res. Inst. appl. Mech.* **2,** 7, 91–109, Sept. 1953.

The author investigates problem of strength of ships' panels. These are networks of horizontal girders and vertical beams in which the effect of the covering plates is neglected. By use of Stieltjes integrals he analyzes the problem of a beam under the action of moments and forces acting at discrete points along the length of the beam. This is analogous to using Dirac delta functions. This fundamental beam solution is then used in analyzing each of the horizontal girders. The equations are set up by using continuity of inclination and deflection at intersections of members, and equilibrium of shear forces and twisting and bending moments at these same points. This yields a set of first-degree equations in the unknown quantities, say, the bending, twisting moments, and the deflections at the intersection points of the panel. Author shows these equations can be solved by iteration methods. A. L. Ross, USA

2146. **Craemer, H., Load-bearing capacity of ideal plastic beam and plates supported on four sides on ideal plastic support** (in German), *Stahlbau* **22,** 9, 200–203, Sept. 1953.

Influence of plastic deformation of supports is demonstrated. It is shown that a minimum strength of support is required to develop the full capacity of the beam or plate. Balanced design requires such considerations. D. C. Drucker, USA

2147. **Blake, F. H., Concrete beams with compression steel—a quick method of design,** *Struct. Engr.* **31,** 8, 219–222, Aug. 1953.

2148. **Younger, D. G., The development of optimum design envelope curves of sheet-stiffener compression panels having Hat, Z or Y-section stiffeners for various materials and temperature environments,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 5–10, Apr. 1953.

Through a use of the wide column theory, a relationship is shown to exist between optimum design envelope curves for 24S-T and 75S-T aluminum-alloy flat-stiffened compression panels. The relationship enables the optimum design envelope curve for either 24S-T or 75S-T to be developed from that of the other, provided the compression stress-strain curves are available for the two aluminum alloys. A method is suggested whereby existing NACA room-temperature data on minimum weight panel designs of 24S-T and 75S-T aluminum alloy can be extended to include other materials, temperatures, and exposure times. Envelope curves at several temperature environments are presented for the optimum sheet-stiffener panel designs having either Hat, Z, or Y-section stiffeners and fabricated from aluminum alloys, titanium alloy, 17-7PH, and 18-8 stainless steel.

From author's summary

2149. Sasse, H., Method of characteristic coefficients for the computation of reinforced and plain members (in German), *Bautech.-Arch.* no. 7, 32–61, 1953.

Formulas are developed expressing the axial and moment load-carrying capacities of rectangular reinforced-concrete sections as functions of the dimensions of the section, the permissible (concrete) stress and characteristic coefficients; these coefficients are plotted as a function of the position of the neutral axis. Additional curves are used to locate the neutral axis for given amount and distribution of the reinforcement or, alternately, to find the reinforcement for the desired location of the neutral axis. In reviewer's opinion, the method suggested is no improvement on calculations in everyday use. G. Sved, Australia

2150. Chilver, A. H., Diffusion of load into the decks of plate-girder bridges, *Engineering* **176,** 4582, 645–648, Nov. 1953.

The composite behavior of structures is receiving increasing attention by research workers to enable a rational and economical analysis to be made. As part of this study, author treats the problems of a uniformly loaded and simply supported plate-girder bridge with a deck consisting of longitudinal stringers that are interconnected either by a single deck plate or by heavy transverse girders.

Using a Fourier series for the longitudinal displacement of the deck, a solution is obtained for the tension stresses in the stringers and the shearing stresses in the deck of the first problem and for the bending moments and shearing forces in the transverse girders of the second problem. The relief of the stresses in the plate girders by composite action with the deck is evaluated and represented in graphical form. Some model experiments with a bridge deck with longitudinal and transverse girders gave reasonable agreement between estimated and observed displacements. G. G. Meyerhof, Canada

2151. Giangreco, E., Instability of equilibrium of polygonal arches (in French), *Publ. int. Assn. Bridge struct. Engng.* **13,** 125–142, 1953.

Based on energy considerations and Dirichlet's theorem, author analyzes the elastic instability of polygonal arches or shells.

After determining the stresses along the edges from the membrane theory, the displacements along the edges are established compatible with the boundary conditions. From the second increment of the potential energy of each face, an expression is obtained for the whole structure and its minimum value gives the solution for the critical buckling load.

An example of the critical load of an arch with five faces illustrates the straightforward method proposed.

G. G. Meyerhof, Canada

2152. Collins, L. E., A preliminary theory for the design of underreamed piles, *Trans. S. Afr. Instn. civ. Engrs.* **3,** 11, 305–313, Nov. 1953.

In a group of houses with experimental underreamed pile foundations at Leeuhof, Vereeniging, it was observed that some 9-in. diam underreamed piles founded at a depth of 30 ft had failed in tension, whereas similar piles founded at 20 ft and 25 ft showed little sign of distress. As a result of this observation an investigation of the tensile forces likely to occur in such piles has been undertaken. An attempt has been made to relate these forces with the properties of the soil at Leeuhof and to develop a design procedure which will permit engineers to calculate the probable tensile forces which will develop in underreamed piles.

From author's summary

2153. Terzaghi, K., Anchored bulkheads, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 262, 39 pp., Sept. 1953.

Author compares classical assumptions in bulkhead design and observational data on the subject, as at present available in technical literature. The investigation shows that discrepancies are too important to be neglected. Experience and experiments indicate that bending moment in the sheet piles, depending on their flexibility, may be considerably smaller than that computed by classical methods.

Based on knowledge gained so far, author suggests that rules regarding the practical should be revised. Limiting values for the factors determining the earth pressure, as well as the margin of safety required in different cases, are given.

K. J. Sundquist, Sweden

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 2117, 2126, 2146, 2153, 2167, 2172, 2179, 2333, 2338)

2154. Sherby, O. D., Orr, R. L., and Dorn, J. E., Creep correlations of metals at elevated temperatures, *J. Metals* **6,** 1, sect. 1, 71–80, Jan. 1954.

For a number of pure metals at temperatures above 0.45 of their melting points, their creep and tensile properties can be correlated by means of the simple relationships: $\epsilon = f(te^{-\Delta H/RT}, \sigma_c)$ and $\sigma_c = f(\dot{\epsilon}, e^{-\Delta H/RT})$ where ϵ is the creep strain, t is the time, ΔH is the energy of activation, R is the gas constant, T is the absolute temperature, σ_c is the creep stress or ultimate tensile strength, and $\dot{\epsilon}$ is the secondary creep rate.

Since the above relationships do not contain a term of the stress divided by the temperature, it was concluded that the stress does not influence the free-energy-of-activation term for the rate-controlling process for high temperature creep. The activation energy from creep data for a given metal was found to be constant for high temperatures (above 0.45% of the melting temperature) at which rapid recovery occurs.

For aluminum, iron, nickel, copper, zinc, platinum, gold, and lead the activation energy for creep is approximately equal to that for self-diffusion and appears to be a periodic function of the atomic number. The activation energy was found to be insensitive to metallurgical factors encountered in this correlation.

M. J. Manjoine, USA

2155. Bailey, R. W., A critical examination of procedures used in Britain and the United States to determine creep stresses for the design of power plant for long life at high temperatures, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-196, 13 pp.

Extrapolation of isothermal data by procedures used in either country is in error because of "thermal action." Thermal action is manifested by variations in creep strength with prior heating. The extrapolation of log creep rate vs. log stress curves, which is done in the United States, is in error even in the absence of thermal action, because of the different shapes of creep curves at different stresses. J. D. Lubahn, USA

2156. Wahl, A. M., Sankey, G. O., Manjoine, M. J., and Shoemaker, E., Creep tests of rotating disks at elevated temperature and comparison with theory, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-61, 11 pp.

Creep tests were run on rotating disks made of 12% chrome steel at 1000 F and the resulting deformations compared with those calculated using tension creep data obtained on the same material. It was found that deformation and creep rates calcu-

lated using the Mises criterion (distortion-energy theory) were lower than those observed. If the maximum shear theory was used, closer correlation was obtained and it, too, yielded conservative values.

Anisotropy of the material was considered to play a major part in the discrepancy between actual and calculated values. Since the maximum shear theory places a larger emphasis on the tangential stress which coincides with the direction of the tension creep specimens, it can be expected to yield closer values. However, since the Mises criterion places more emphasis on the axial stress and this direction was not tested in tension creep, it is not unexpected that this theory would not yield accurate calculations.

It was recommended that the maximum shear theory be used since it yielded conservative results; however, some caution must be exercised since the anisotropy of the material may be such as to reverse the trend described in this paper. This paper is one of the first to present creep data on rotating disks and is consequently recommended reading for the designer.

A. D. Schwope, USA

2157. **Dugdale, D. S., Wedge indentation experiments with cold-worked metals,** *J. Mech. Phys. Solids* **2,** 1, 14–26, Oct. 1953.

Experiments on the plane-strain indentation of mild steel, copper, and aluminum blocks are reported. It is shown that the breadth of indentation and the applied load are linearly related if the dimensions exceed stated critical values. The mean yield shear stress and the mean shear strain are computed, based on slip-line field theory modified to take account of observations. Author shows that reasonably close agreement with the values obtained from torsion tests exists. The shape of the lip of displaced metal is found to be close to that predicted for a plastic-rigid material. The homogeneity and isotropy of the work material were examined and average values taken where necessary. Allowance was made for friction.

The mechanics of deformation for the commonly used indentation tests is not known and hence their true significance is doubtful. The theory of wedge indentation for a plastic-rigid material is known. This paper is a commendable attempt to relate the results of wedge-indentation tests to a fundamental material property. J. F. W. Bishop, Scotland

2158. **Vasilyev, L. I., Bylina, A. S., and Zagrebennikova, M. P., On the effect of change in deformation rate on plastic deformation,** Nat. Sci. Found. tr-138, Dec. 1953; *Dokladi Akad. Nauk SSSR* (*N.S.*) **90,** 5, 767–769, June 1953.

The increase in the deformation rate apparently results in a qualitative change in the spatial distribution of deformation distortions and in an increase of their "variety" (e.g., with respect to their stability at a given temperature). In this connection, it seemed interesting to determine the effect of the change in the deformation rate (from a higher to a lower rate, and vice versa) on the process of plastic deformation.

Experiments were made at room temperature with polycrystalline copper and tin. From authors' summary

2159. **Brull, M. A., A structural theory incorporating the effect of time-dependent elasticity,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 141–147, Apr. 1953.

This paper contains a general analytic formulation of the deformation of elastoviscous bodies represented by combinations of Maxwell models (spring-dashpot).

It is proved that the time-dependent elasticity solution to any problem is obtained by taking the Laplace transform with respect to time of the elastic solution, replacing the shear modulus by a factor containing the viscosity coefficient in the relation between shear stress and time rate of plastic flow, and then performing the inverse Laplace transformation.

This interesting approach expresses in a synthetic analytic form an analogy between elastic deviation strain and plastic flow comparable to the one outlined by A. A. Ilyushin ["The deformation of a viscoplastic solid," *Uch. Zap. Mosk. Gos. Univ., Mekh.* **39,** 1–81, 1940; Transl. NObs-34166, Brown University, 1947].

The application of the theorem to real materials should be limited by the condition that the theorem is valid in those regions where the shear stress is higher than the static stress corresponding to the plastic strain present. Regions of the considered structure where the shear stress is lower than the minimum necessary to produce flow will undergo elastic strain but no plastic flow. Such regions may vary in extension during the studied deformations. C. Riparbelli, USA

2160. **Lee, E. H., A geometrical construction for plastic flow with work hardening,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 136–140, Apr. 1953.

Paper presents a convenient way of showing, in a plane diagram, that the relations between the principal components of deviatory stress and strain increment in a nonhardening plastic-elastic material were first proposed by Reuss. This construction was later extended by Hill to a work-hardening material. Author here considers a special case of the latter construction when the elastic part of the strain is negligible. Method is illustrated in relation to a thin cylindrical tube loaded by certain combinations of internal pressure and axial tension. R. Hill, England

2161. **Riparbelli, C., On the time lag of plastic deformation,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 148–157, Apr. 1953.

Author gives experimental data on the relation between stress, strain, and velocity in a bar submitted to longitudinal impact. The deformation is considered as the resultant of two parts: (a) the elastic elongation, and (b) the flow deformation which grows locally as an effect of the stress present, according to a relation which is investigated in this paper. The material used is copper and the deformation was detected by means of strain gages and oscilloscopes at different points along the bar. The main results are: (a) In a prestressed bar, the front of a deformation wave propagates with the same velocity as elastic waves and the plastic deformation will follow in time in form of creep; and (b) the time derivative of the creep deformation is proportional to the "excess of stress" established simultaneously with the elastic component of deformation. Th. Pöschl, Germany

2162. **Torre, C., Theory of elastoplastic and viscoplastic materials** (in German), *ZAMM* **33,** 8/9, p. 300, Aug./Sept. 1953.

Paper deals with general stress-strain-velocity equations of viscoplastic materials, which are derived by addition of stress-velocity and stress-strain relations of elastoplastic materials under the assumption that the strain is sufficiently small. Introducing the arithmetic mean of normal stresses into the basic equations, author obtains the formal coincidence of these equations with analogical equations of hydrodynamics. Finally, the equation of motion for viscoplastic continuum is introduced.

V. Kopřiva, Czechoslovakia

2163. **Kochendörfer, A., The basic laws of flow of amorphous and crystalline substances** (in German), *Z. angew. Phys.* **5,** 2, 69–80, Feb. 1953.

Author gives clear and readable survey of recent progress with respect to basic physical phenomena which control viscous and

plastic properties of amorphous and crystalline materials. Emphasis is put on interchange of molecules as the basic phenomenon of viscosity and on movement of dislocations as the basic feature of plastic deformation. Temperature effect is fully discussed. Bibliography includes more than 50 references.

W. T. Koiter, Holland

2164. Pao, Y.-H., and Marin J., Prediction of creep curves from stress-strain data, *Proc. ASTM* **52,** 7 pp., 1952.

On the assumption that at any time the total strain is the sum of the elastic and creep strains, authors develop a semigraphical method for estimating creep-time relations for constant stress. The method, based on stress-strain curves for constant stress at various rates of strain, is found to be in good agreement with test data on Plexiglas, except for higher stresses.

Apart from the difficulty of approaching infinite strain rates to determine elastic strains and the modulus of elasticity, the proposed method requires further checking with experimental data before accepting it for extrapolating short-term laboratory test results to the prediction of creep deformation during the lifetime of machines and structures. G. G. Meyerhof, Canada

Failure, Mechanics of Solid State

(See Revs. 2078, 2100, 2179, 2181)

Material Test Techniques

(See also Rev. 2173)

2165. Tabor, D., Mohs's hardness scale—a physical interpretation, *Proc. phys. Soc. Lond.* (*B*) **67,** part 3, 411B, 249–257, Mar. 1954.

The Mohs hardness scale consists of 10 minerals arranged in increasing order of hardness such that each mineral will scratch the one on the scale below it, but will not scratch the one above it. Although these minerals are generally considered to be brittle, experiments show that under local indentation and during sliding their behavior is primarily determined by the plastic properties of the minerals. This suggests that there should be some relation between the Mohs hardness and the indentation hardness of the minerals.

Experiments with metals show that, in general, a metal surface of indentation hardness H_s will be scratched by a point of hardness H_p if $H_p \geqslant 1.2H_s$. Thus a scratch hardness scale can be constructed in which each standard has an indentation hardness at least 1.2 times greater than the preceding standard. The scratch hardness number is then proportional to the logarithm of the indentation hardness. Excluding diamond, which is anomalous, this type of relation is found to apply to the Mohs standards, and it is found that each standard is approximately 60% harder than the preceding one. From author's summary

2166. Onitsch-Modl, E. M., Microhardness testing in theory and in practice (in German), *Schweiz. Arch.* **11,** 19, 330–342, Nov. 1953.

Purpose of paper is to show the many possibilities of microhardness testing which is applicable to small and thin pieces (or layers), microconstituents, etc., and enables, e.g., obtaining additional information on transformations in solids.

A series of technical apparatus based on Vickers indenter covering all loads from 1g onward is now available. Experiments in metals show that Meyer constant n for Vickers indenter not only differs from 2 but also varies with load if determined over a wide load range. However, to some degree this is also the case for macro-Vickers at lower loads, hence behavior is fundamentally the same. Characteristic examples of application of microhardness testing on metals, glass, and pencil leads are given.

J. H. Palm, Holland

2167. Mohr, E., Estimation of the "true" elastic limit by aid of the bending-tension experiment (in German), *Forsch. Geb. Ing.-Wes.* **19,** 2, 33–43, Aug. 1953.

The history of the bending-tension experiment is reviewed and the application of this test method is described, especially as used for the determination of strength values and for the testing of uniformity of sheet materials. The paper deals in detail with the coherences of the true elastic limit, fatigue strength, and bending tensile strength, and, in connection herewith, the laws of Bauschinger.

The test method is a static-dynamic test; it is also a rapid method, because the duration of test is only a few hours. The test pieces, in strip or wire form, are loaded with a static tensile stress and then bent backward and forward with a small bending angle in the range of ± 6 to $\pm 14°$ in a to-and-fro bending tester until fracture is determined, lying in the range of nearly 10 to 5000 bends. The tensile stress is plotted as a function of the logarithm of the number of reversals; this graphical representation gives the bending-tension curve, generally showing three turning points. The tensile stress at the first turning point is presumably identical with the bending fatigue strength, determined in fatigue tests with stress reversals of 10^7 to 10^8. It is noticeable that the stresses at the turning points are dependent on the test conditions, especially of the bending angle, thickness of sheet, and diameter of bending rolls.

The test results are reproduced for specimens of seven light-metal alloys, one mild steel, and electrolytic copper. The specimens are tested in the form of rolled sheets with a thickness of 0.06 in., and with a most favorable bending angle in the backward and forward bending tests between ± 7 and $\pm 10°$. The divergences of the fatigue strength under reversed bending stress and the bending tensile strength of the different materials are in the range of -3.5 to $+8.5\%$. Determination of the notch sensitivity in bending tension experiments is reported at the end of the paper. M. Hempel, Germany

2168. Baud, R. V., Testing of concrete by acoustical methods (in German), *Schweiz. Bauztg.* **71,** 38, 554–555, Sept. 1953.

The Swiss Society for Testing Materials sponsored a symposium on "Testing of concrete by dynamic methods." Four different types of equipment were discussed. Two of these are suitable for laboratory work, and two for field testing.

The first equipment described for laboratory application makes use of the resonance principle. An ultrasonic wave is transmitted into a test specimen. The longitudinal resonant frequency is determined. Knowing the dimensions of the specimen (length 1 to 20 cm) and the resonant frequency, the velocity of sound in the specimen can be calculated. This velocity is considered an indication of the strength characteristics.

The other three equipments determine the velocity of sound in the concrete by a measurement of the elapsed time between the transmission and the receiving of a pulse. The length of the path between the point of transmission and the point of reflection, or the point of pulse reception if two transducers are used, is known. Measured are the velocities of longitudinal compression waves, shear waves, and surface (Rayleigh) waves.

The second equipment mentioned, also suitable for laboratory work, utilizes the same transducer as transmitter and receiver. The transducer is made of quartz or of barium titanate. The third and fourth equipments are suitable for field work.

The pulses are generated by means of a mechanical hammer or by means of explosions. The elastic constants (modulus of elasticity and Poisson's ratio) are determined from two of the measured sound velocities. Proper interpretation of the measurements may also give indication as to the presence of flaws, the depth of layers of different materials, and the positions of reinforcing rods in the structure. Structures tested are airport runways, dams, etc.

Also discussed are the validity of determining the strength of the concrete from the elastic constants and the question of other parameters entering the relation. Such parameters are internal friction, frequency, etc. Also discussed is the question as to whether "the static and the dynamic modulus of elasticity have the same values." R. O. Fehr, USA

2169. **Ault, N. N., and Ueltz, H. F. G., Sonic analysis for solid bodies,** *J. Amer. ceram. Soc.* **36,** 6, 199–203, June 1953.

Sonic methods were used to investigate the effect of temperature on Young's modulus of ceramic materials. Single-phase, two-phase, and multiphase systems were represented in the materials investigated. The effect was strongly dependent on the material and could be either positive or negative. The authors postulated three causes for temperature effects: (1) Thermal agitation, which weakens the atomic lattice as the temperature is raised; (2) introduction of a new phase by inversion, the new phase having a different modulus; and (3) differential expansion within the body. W. H. Duckworth, USA

2170. **Mönch, E., Improvement of plastic compression test by using forced friction** (in German), *Z. angew. Phys.* **5,** 10, 363–369, 1953.

In photoelastic analysis, restraint due to friction in compression is a serious problem, especially for large strains. Author presents novel but complicated procedure to overcome the difficulty. Compressive force is applied obliquely to surface so that tangent of angle between normal to plane and force vector equals coefficient of friction. Surface of specimen is lubricated to minimize friction. Loading platens are moved laterally so that slip and tangential force component offset friction. Difficulty arises in equally offsetting friction on top and bottom surfaces; hence test is warranted only when especially good data are required.

Results of tests on both celluloid and pure aluminum show excellent performance as indicated by photoelastic analysis and specimen distortion up to 0.3 true strain ($\log(1 + \epsilon)$). True stress-strain curves for tension and compression were practically coincident until tensile failure. Stress optical properties in tension and compression diverged at increasing rate after strain of 0.01. While this does not affect most photoelastic analyses, it is of serious concern when specimen undergoes high strains.

F. J. Mehringer, USA

Mechanical Properties of Specific Materials

(See also Revs. 2144, 2258, 2328)

2171. **Enos, G. M., and Fontaine, W. E., Elements of heat treatment,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1953, 286 pp. $5.

This clear, well-illustrated presentation of the fundamentals of heat-treating steel starts with discussions of the nature of metals and alloys and of the mechanical properties of metals and proceeds through the various methods of heat-treating—namely, annealing, normalizing, quenching, and tempering. Chapters are also devoted to the concepts of hardenability, the various grades of alloy steels, and the surface-hardening of steel. In addition, discussions of the heat-treatment of cast irons and of nonferrous metals are presented.

This book should be of considerable value to the specialist in fields other than metallurgy who must have some knowledge of the principles of heat-treatment. The book developed from notes used in a college course presented to freshmen in engineering.

J. A. Bauscher, Jr., USA

2172. **Newhouse, D. L., Seguin, B. R., and Lape, E. M., Some 12 per cent alloys for 1000 F to 1200 F operation,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A–168, 21 pp.

Paper presents a discussion of important engineering properties of some martensitic 12% Cr alloys for use at temperatures up to 1200 F. Detailed high-temperature creep-relaxation and stress-rupture data are given for 12% Cr (Type 403) and for six alloy modifications, including 12% Cr-Co-W-V, 12% Cr-W-V, 12% Cr-Mo-V, 12% Cr-Mo-W-V, 12% Cr-Cb, and 12% Cr-Ni-W. Other properties such as thermal expansion, modulus of elasticity, resistance to stress corrosion, and so forth, are discussed. Some of the modified 12% Cr alloys offer a combination of properties which make them attractive for a number of high-temperature applications. From authors' summary

2173. **Bardgett, W. E., Comparative high-temperature properties of British and American steels,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-195, 14 pp.

Creep tests on identical steels at different laboratories have similar results if the steels are ferritic, but have markedly different results for austenitic steels. Steels made to the same specifications by different countries were more likely to show similar creep behavior if they were ferritic than if they were austenitic. J. D. Lubahn, USA

2174. **Kemper, H., and Pomaska, W., Influence of flame-cleaning on the properties of steel** (in German), *Mitt. Beratungsstelle für Autogen-Technik EV (BEFA)* no. 9, 20 pp., 1953.

Gases, dusts, and vapors in flame cleaning are treated. Kind and quantity of removable rust, temperatures, influence on structure of structural steels, influence on strength under static stress and on aging, influence on endurance limit of structural steels, internal stresses, and comparative tests of cleaning techniques with regard to corrosion resistance of steels are discussed. From authors' summary

2175. **Hubbell, W. G., Jet metals,** *Aero. Engng. Rev.* **12,** 9, 31–36, Sept. 1953.

2176. **Delbart, G., and Ravery, M., Influence of microstructure on the hot strength of steel,** *Metal Treatm.* **20,** 99, 579–590, Dec. 1953.

The work reported in 1950 on the effect of heat-treatment on the rate of creep of low-carbon CR-Mo steels at various temperatures has been extended by the authors under the auspices of the IRSID creep-testing committee. Long-time tests for 1000 hr were carried out at 450 C and 575 C, and the influence of preliminary heating and soaking investigated.

From authors' summary

2177. **Van Wijk, F., Depth of hardening in steel** (in Dutch), *Metalen* **8,** 22, 401–406, Nov. 1953.

A concise survey is given of the theory on the depth of hardening in steel. The three factors controlling depth of hardening—hardenability, severity of quench, and dimensions of the quenched piece—are discussed. Though a generally valid criterion for equivalence of temperature-time cooling curves with respect

to austenite-transformation products can hardly be hoped for, the importance of a good method for roughly predicting hardness values is emphasized. As an illustration, the method of Lamont is given. From author's summary

2178. Isibasi, T., and Uryu, T., Fatigue strength of carbon steel bars with round-crack, *Rep. Res. Inst. appl. Mech., Kyushu Univ.* **2,** 6, 65–75, June 1953.

Fatigue cracks were generated in circumferentially notched bars in rotary bending, after which the machined notch was turned off, leaving circumferentially cracked specimens. Fatigue strength of such specimens as a function of crack depth was determined for three steels of 0.08, 0.12, and 0.53% carbon and compared with fatigue strength of smooth-bar specimens. Ratio of smooth-bar to cracked-bar fatigue limit increased with depth of crack, independently of carbon content. Annealing after cracking was detrimental. G. V. Smith, USA

2179. Carlson, R. L., and Schwope, A. D., An experimental investigation of the creep properties of aluminum at elevated temperatures, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 180–183, Apr. 1953.

An experimental investigation of the behavior of 24S-T4 (stabilized) aluminum columns at three elevated temperatures has been conducted. Tests were performed on long- and short-hinged end columns of four slenderness ratios. By using an adjustable end eccentricity, it was possible to fix the eccentricity for a column of a given slenderness ratio and thereby obtain comparable results for different loads. Deflection measurements were taken at the midpoint throughout the duration of each test, and curves of deflection versus time, with load as the parameter, were obtained for each slenderness ratio. Test results indicate that, for a column of a given slenderness ratio and eccentricity, there is a limiting load below which collapse due to creep will not occur. It is concluded that this lower limit should be considered the limiting or allowable load. From authors' summary

2180. Giedt, W. H., Sherby, O. G., and Dorn, J. E., The effect of dispersions of creep properties of aluminum-copper alloys, ASME Ann. Meet., New York, Dec. 1953. Prep. 53—A-78, 8 pp.

Creep tests are described which show that the creep properties of the alloys containing 3 to 5% Cu vary in the temperature range between 75 and 300 C primarily with the degree of dispersion of the precipitated $CuAl_2$ particles. They are independent of minor variations in composition and heat-treatment. The coarser dispersions are superior at intermediate temperatures, whereas the finer dispersions are more creep-resistant at lower and higher temperatures. The temperatures at which the inversion occurs depend upon the strain rate. These results are similar to those obtained in tensile tests, and they are explainable in terms of recovery.

The relationship between secondary creep rate and temperature is expressed using the Zener-Holloman relation. Fairly good agreement with the data is obtained if the activation energy is assumed to be 37,000 cal per mole. A. W. Cochardt, USA

2181. Welber, B., and Webeler, R., The energy state of fatigued copper, *J. Metals* **5,** 11, sect. 2, 1558–1559, Nov. 1953.

Since fatigue is believed to result in work hardening, a measurable amount of strain energy is likely to be recovered upon reheating of a fatigued metal. On this supposition, comparative calorimetric measurements were made of energy input required to heat OFHC copper specimens in (a) annealed, (b) annealed and cold-twisted, and (c) annealed and fatigued condition, from 20 to 450 C.

The respective amounts of external energy required in the three cases were related in such a way that $(b) < (a) < (c)$. Evidently no strain energy was absorbed by the fatigued samples (c).

Without attempting to offer an explanation for the phenomenon, authors point out the apparent disagreement between their results and the prevailing views on the nature of fatigue.

N. H. Polakowski, USA

2182. Maykuth, D. J., High purity metals, *Prod. Engng.* **24,** 11, 186–190, Nov. 1953.

Author emphasizes fact that the mechanical and physical properties of nominally pure metals are often controlled and occasionally obscured by the presence of minor impurities. Salient properties of high-purity Zn, Al, Fe, Mo, Cr, Ti, and Zr are discussed. L. Green, Jr., USA

2183. Seidel, K., Change of compression strength of concrete by changing size of largest particle (in German), *Beton u. Stahlbeton.* **49,** 2, 42–45, Feb. 1954.

2184. Eisenmann, K., and Steinkamp, G., Measurement of depth and width of cracks in concrete with aid of ultrasonics (in German), *Beton u. Stahlbeton.* **49,** 2, 36–38, Feb. 1954.

2185. Blackman, J. S., Method for estimating water content of concrete at the time of hardening, *J. Amer. Concr. Inst.* **25,** 7, 533–540, Mar. 1954.

2186. Calleja Carrete, J., New techniques to investigate the setting and hardening of hydraulic cements. II. Study of some of the variables which affect setting (in Spanish), *Inst. tecn. Constr. Cem. Publ.* no. 134, 63 pp., 1953.

2187. Bergström, S. G., An experimental study of the relation between the properties of fresh and hardened concrete, *Publ. int. Assn. Bridge struct. Engng.* **13,** 49–73, 1953.

2188. Thring, M. W., Potential uses of super-refractories, *Research, Lond.* **7,** 2, 54–59, Feb. 1954.

2189. Stern, E. G., Strength of Auto-Nailer assembled skids of green and dry lumber, Virginia Polytechnic Institute Wood Research Laboratory Bull. no. 12, 24 pp., Dec. 1953.

Auto-Nailer jointed skids showed under given conditions greater effectiveness than corresponding skids jointed with plain-shank nails. Thus, certain Auto-Nailer assembled skids were (a) considerably stiffer and demonstrated a larger load-carrying capacity when under edgewise compression and were (b) considerably more rigid and offered larger torsional resistance when twisted in a torque-applying testing machine.

The possible advantages are demonstrated of using lighter 16-gage instead of 15-gage wire, $1^1/_2$ in. long instead of shorter auto nails, deeper countersinking than $^1/_{32}$ in., and clinching versus bradding of auto nails.

The feasibility is also illustrated of effectively auto-nailing $^3/_4$-in. thick and thinner slats on the one hand and green and dry slats on the other hand into skids of same-thickness lumber.

From author's summary

2190. Voong, E. T. L., and Montgomery, D. J., Experimental study of stiffness and nonuniformity in the vibroscopic determination of fiber cross-sectional area, *Textile Res. J.* **23,** 11, 821–830, Nov. 1953.

An experimental investigation has been made of the effect of

stiffness and nonuniformity in filaments on the vibroscopic determination of linear density. For the samples studied (tungsten wire, wool fibers, nylon filaments), the effect of damping and of support motion was ordinarily negligible. The effect of stiffness in raising the natural frequencies follows theory, as does the effect of nonuniformity in changing the natural frequencies and in shifting the nodes. When appropriate corrections for these effects are made, the vibroscope provides an accurate method for determining linear density of filaments, the values found agreeing with direct weight determinations within the precision of the weighing. From authors' summary

Mechanics of Forming and Cutting

(See also Rev. 2363)

2191. **Jung, H., Calculation of the blank-holder pressure in deep drawing** (in German), *Öst. Ing.-Arch.* **7**, 4, 273–284, 1953.

Using results of part I [AMR **7**, Rev. 1798], it is established that the effect of blank upsetting on the blank-holder pressure is not negligible. Conditions for wrinkle formation are set forth. Method of calculating the blank-holder pressure is discussed and values thus ascertained are found to agree with experimental ones. D. Kececioglu, USA

2192. **Szöke, P., The cold drawing of gears** (in Hungarian), *Magyar Technika* **7**, 7–8, 443–447, July-Aug. 1952.

A new method of manufacturing gears, cold-drawing, is described. This method is carried out in the same manner as the cold-drawing of tubes. The accurate gear profile is obtained in 5 to 6 steps from a steel bar with a circular section. The bars must be annealed, pickled, and phosphated between each drawing operation. Gears are manufactured by subsequent machining from the bars drawn to size. The gears are cut off one at a time after providing the bar with a through bore. The manufacture of gears has been stepped up considerably since the teeth of a great number of wheels are cut simultaneously in the drawing process. As shown by approximative calculations, the time required for toothing a gear to accurate size is, on the average, 0.29 min. The possibilities exist for also manufacturing splined shafts, adjustable reamers, feed shafts, etc., by this method.
Courtesy of Hungarian Technical Abstracts P. Széky

2193. **Usui, T., and Miyagawa, M., On deep drawing of aluminum sheet metal without blankholder,** *Mem. Fac. Technol., Tokyo Metrop. Univ.* **28**, 3, 95–110, 1953.

Slow-speed drawing test utilizing flat-headed punch and die of fixed diameter (= 40.60 mm). Parameters taken into account are blank thickness t and diameter D, punch clearance c, punch chamfer radius r_p, type and method of application of lubricant.

Punch-travel vs. drawing-force records show a single maximum in case of pure drawing, but two maxima when ironing takes place (small clearance). Maximum drawing force is plotted against variable drawing ratio for different values of c/t. Effect of lubrication on drawing force is pronounced only when severe ironing is involved, surface-active fatty lubricants being superior to mineral oils and greases.

Results are believed to be of some interest in the part dealing with lubrication. No comparison with other similar work is attempted and no references are cited.
N. H. Polakowski, USA

2194. **Mamillan, M., Tests performed on gyratory crusher** (in French), *Ann. Inst. tech. Bât. Trav. publics* **6**, 72, 1135–1156, Dec. 1953.

Tests performed on a gyratory crusher lead to the following conclusions: (1) A diminution of the rotating velocity of the crushers below the theoretical optimum velocity entails an increase of the power consumed per ton, a decrease of the output, an increase of fines and flat particles. (2) If the reduction is increased, the fines and the power consumed increase, the shape of the fragments is improved, the output is reduced. (3) The process of presieving the unsorted material entails the following changes: The percentage of fines reduced; the product obtained is more selective; the output increases; the power consumed per ton is decreased. (4) If all the characteristics of the fragmenting mechanism are constant and the rock resistance increases, the shape of the fragments is less cubical, the output and the energy consumed per ton increase, the size of the product obtained is larger, the fines are decreased, and the fragmentation is more selective.
From author's summary

2195. **Joisel, A., and Birebent, A., Mechanics of ball milling** (in French), *Rev. Matér. Constr.* nos. 434, 435, 436, 437, 438, 439; 311–320, 347–355, 7–12, 46–52, 69–74, 93–101; Nov., Dec. 1951, Jan., Feb., Mar., Apr. 1952.

Authors present a study, in two parts, of theory and practice of ball milling to (1) clarify the understanding of principle of operation, (2) provide quantitative information on optimum rotational drum speed and volumetric percentage of material charged in the drum, (3) prove correlation between theoretical findings and experimental data.

Part I includes mathematical analysis of path followed by the material in the rotating drum, efficiency of milling at the point where the falling balls meet the inside surface of the drum, power used in milling, and calculation of volume charged. Analysis is based on assumption of (1) parabolic, (2) transcendental path of the material, and (3) constancy of volume of the material charged in the drum. First two assumptions have been proposed and partially analyzed in the past, but are re-examined and more completely analyzed by authors. Third assumption is new and is proposed by authors to avoid deficiencies of previous theories.

Part II relates results of tests which prove satisfactory relation with theoretical findings of part I, regarding speed of operation of drum and volumetric charge. The presentation is impressive for the thorough treatment of the subject, is well illustrated by graphs, and marks an advance in the science of ball milling. This study should prove valuable to all those who are concerned with the production of powdered material by ball milling.
M. Martellotti, USA

2196. **Polosatkin, G. D., Relation of (abrasive) wear to the grinding area,** Nat. Sci. Found. tr-42, Aug. 1953; *Doklady Akad. Nauk SSSR (N.S.)* **88**, 6, 971–973, Feb. 1953.

Paper deals with experimental verification of a theoretical relation (which is probably semiempirical) between the amount of metal removed by grinding and the nominal grinding area. This relation was formulated by analogy with results obtained in metal-cutting research previously carried out by the author and Kuznetsov.

Reviewer believes that use of the term "abrasive wear" for the amount of metal removed in a grinding operation is misleading. Grinding of metals is essentially a cutting process on a microscopic scale. B. T. Chao, USA

2197. **Shiozaki, S., Research on cutting residue of grinding-stone and roughness of ground surface,** *Mem. Fac. Technol., Tokyo Metrop. Univ.* **28**, 3, 83–93, 1953.

Author points out that maximum peak-to-valley distance on surfaces ground with abrasive wheels may be a substantial fraction of wheel depth of cut. He calls the material remaining on

surface above level of deepest grooves "cutting residue" and develops analytical expressions for its height in external and internal cylindrical grinding and surface grinding. Height of cutting residue is found to be a function of velocities of wheel and work, dimensions of wheel, diameter of work (cylindrical), number of abrasive grains per unit area of wheel face, wheel depth of cut, longitudinal feed per revolution (cylindrical grinding), and cross feed (surface grinding). Author obtains good agreement with experimental values determined by taking difference between wheel depth of cut and reduction in work radius as measured with a Zeiss indicating micrometer. He also obtains good correlation between calculated height of cutting residue and surface roughness measured with a tracer-type instrument.

H. R. Letner, USA

2198. Romanov, V. F., and Yakimanskiĭ, V. V., The design of a rotary shaver (in Russian), *Stanki i Instrum.* **24,** 5, 13–17, May 1953.

An elementary step-by-step method of calculating rotary shavers adopted in one of the Russian automobile plants is described. Method comprises determination of geometry of new tools and corrections applicable to reground shavers. Article can be of interest to practical tool designers.

J. J. Dziewonski, England

Hydraulics; Cavitation; Transport

(See also Revs. 2081, 2097, 2280, 2352)

2199. Mukherjee, A. K., On the relationship between fluidity and surface tension of liquids, *J. Indian chem. Soc.* **30, 10,** 670–674, Oct. 1953.

An equation connecting fluidity of a liquid with its surface tension has been deduced from considerations of free volume in the liquid state. The equation appears to be more liberal in its outlook than Newton Friend's empirical equation for the same.

From author's summary by M. J. Goglia, USA

2200. Ohji, M., A note on the laminar flow in the inlet length of a circular pipe, *Rep. Res. Inst. appl. Mech., Kyushu Univ.* **2,** 6, 75–79, June 1953.

2201. Marchi, E., Two-dimensional flow of water from an opening (in Italian), *Ann. Mat. pura appl.* (4) **35,** 327–341, 1953.

Theoretical research on the coefficient of contraction of a rectangular orifice, lying under a plane sharp-edged gate; influence of gravity field is taken into account. The study is based on a suitable simplifying hypothesis about the shape of the velocity hodograph along the free surface. In particular, discharge coefficients are calculated for gates vertical or inclined at 60°, 45°, and 30°; results, compared with Gentilini's experiments, are found satisfactory.

D. Citrini, Italy

2202. van Hecke, A., Theory of the movement of fluids (in French), *Bull. tech. Union Ingénieurs sortis Écoles spéciales de l'Univ. Louvain,* no. 3–4, 71 pp., 1952.

Author proposes a semi-empirical formula, deduced from the results of most of the well-known measurements of the pressure-drop in turbulent flow in cylindrical tubes. The most difficult point is to make due allowance for the influence of the roughness of the walls of the tube. After much numerical work, author presents a formula, which is perhaps too complicated for engineering practice. Also, some of the measurements do not agree satisfactorily with the formula; see the curves on pp. 47–63.

The calculations seem to be correct except perhaps for the considerations about the slip at the walls. The investigations are continued.

O. H. Faxén, Sweden

2203. Escande, L., Stability condition in surge tanks mounted on a venturi tube (in French), *C. R. Acad. Sci. Paris* **238,** 2, 183–185, Jan. 1954.

A first-order formula is given for minimum area of a cylindrical surge tank required for stable operation with constant power delivery. Author states that the normally used formula of Thoma (1910) is not quite correct and derives his formula neglecting changes in kinetic energy of the flow underneath the entrance to the surge tank, in contrast to the Thoma formula.

H. J. Schoemaker, Holland

2204. Emmons, E. W., Pearson, C. E., and Grant, H. P., Compressor surge and stall propagation, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-65, 13 pp.

It is well known that fluid pumps and compressors are only able to operate smoothly and efficiently within a certain region of the work-flow map, and that to the left of a critical ("surge") line, which is not clearly defined, the steady-flow pattern breaks down. The behavior of the flow in the unstable region has been studied by many workers, but the present article gives the most detailed observations published to date.

Measurements of the fluctuating velocity were obtained with a hot-wire anemometer probe, at several points within two single-stage compressors (one axial and one centrifugal flow) and behind a cascade. Two distinct types of fluctuation were found, sometimes superposed: (1) Acoustic resonance between the entry and exit ducts. (2) The propagation of blade stall around the annular rows, giving a pulsating frequency lower than that of the rotor. The theory of the first type is given; the second is discussed qualitatively.

The work is of greater engineering interest than merely as a guide to the behavior of single-stage fans, for: (1) It may be possible to extend it to the surging of multistage compressors. (2) In single-shaft high-pressure-ratio axial compressors, driven by gas turbines, the first stage becomes stalled at quite high speeds even if the whole compressor is operating well within the stable region. So one of the most important problems in design is to insure that this stalling is not violent, for the associated vibration can (and often does) wreck the whole machine. The article makes a valuable contribution to an understanding of this problem, although it does not provide a solution.

J. M. Stephenson, USA

2205. Hellstrom, B., Fan-shaped outlets, *Houille blanche* **8,** 6, 873–880 (French text, 881–882), Dec. 1953.

Scale-model investigations were made on seven models (one main model, scale: 1/60, and six supplementary models, scale: 1/180) of two flood-outlet canals, one on each side of a rock-fill dam. The downstream ends of both canals are 12 m above extreme high water level in the river. They are designed for a discharge of 5500 m^3/sec each. Arrangements are developed which enable maximum reduction of agitation and consequent damage to bed or structures by water jets.

From author's summary

2206. Eastwood, W., Taylor, G. A., and Allen, J., Scale-model experiments on high-head siphons and vortex chambers connected thereto, *Proc. Instn. civ. Engrs.* **2,** 5, part 1, 556–584, 2 pp. of figs., Sept. 1953.

Author studies the characteristics of a siphon connected to a vortex chamber in order to avoid the passage of air into a high-

pressure tunnel. The first part constitutes a general study of the siphons—discharge, pressures at critical sections, priming conditions. The second part describes the experiments carried out with vortex chambers of different sizes.

Scale models and glass siphons of different forms are used in these experiments to determine the conditions of air propagation; then, observing the movements of air bubbles through glass, vortex chambers of various sizes are added. These experiments show that the vortex chambers allow release of air carried down in the siphon before passing into the high-pressure tunnel.

This study is very interesting in the case of water intakes, to allow the release of air carried down in the siphon constituting the intake and to avoid its introduction into the high-pressure tunnel. L. Escande, France

2207. **Mosonyi, E., and Kovács, G., Small models for the joint consideration of the forces of gravity and friction** (in Hungarian), *Hidrológiai Közlöny* **32,** 7/8, 274–277, July/Aug. 1952.

Besides the Reynolds number and Froude's law, the introduction of a new model law is recommended which is suitable for joint consideration of the forces of gravity and friction. The possibility of applying these formulas to slightly distorted movements of underground waters in porous media is discussed. The proposed equations can be best used in research and for the evaluation of fluid movements in porous strata and in model experiments conducted on various scales. According to the new law, a mechanical similarity exists in respect to the undistorted model, as regards the joint effect of gravity and friction forces, when the computed values are identical in the model and in reality.
Courtesy of Hungarian Technical Abstracts P. Mazalán

Incompressible Flow: Laminar; Viscous

(See also Revs. 2227, 2235, 2236, 2253, 2297)

2208. **Kaplan, C., Incompressible flow past a sinusoidal wall of finite amplitude,** *NACA TN* 3069, 26 pp., Feb. 1954.

Author first studied the stated problem by using the well-known method of small disturbance and was able to show that the problem is more properly treated in the plane of complex velocity potential rather than in the plane of physical flow, although for the linearized case they both lead to the same result. Author further compared two iterative approaches to the solution of the problem, one based on an expansion of the solution into powers of the amplitude parameter ϵ, known as the method of small disturbance referred to above; and the other by setting up the problem in the form of an integral equation and then solving by way of successive approximation, much in the manner of the method of Theodorsen and Garrick. A numerical evaluation for the case $\epsilon = 0.7$ was carried out. Results indicate that the integral equation approach is superior both in accuracy and as regards the possibility of proceeding to higher approximations. The above trend is believed to be generally true for aerodynamic problems. H. S. Tan, USA

2209. **Einstein, H. A., and Li, H., Vortex motion in viscous fluids studied in apparatus consisting of concentric glass cylinders,** *Civ. Engng., N. Y.* **23,** 9, p. 51, Sept. 1953.

2210. **Venkataraman, S., Oscillation of viscous liquids in tubes and the criterion of stream line motion,** *Indian J. Phys.* **27,** 9, 452–456, Sept. 1953.

Author conducted experiments on the oscillatory motion of a viscous liquid in a U-tube and found that over a certain range the logarithm of the amplitude of oscillation decreases linearly with time. The viscosities of five different liquids are measured by author with his apparatus. Compared with the viscosities given by the International Critical Tables, author's results are excellent for three liquids, fair and poor for the other two.

Author's interpretation of his experimental results is based on Lamb's solution (in which body force is not considered) for the decay of an arbitrary initial motion of a viscous liquid in a straight circular cylinder, but he does not state in what way and to what extent Lamb's solution is pertinent to his experiments. The much more pertinent theory of Yamada and Taneda [*Rep. Res. Inst. Fluid Engng., Kyushu Univ.*, **7,** no 1, Sept. 1950] is not used. The same authors' experiments, as well as the recent experimental works of Valensi (Marseille) and Sackmann (Strasburg) in the same field are not quoted. Also, author's intention to study the turbulent motion of oscillating liquids experimentally, announced at the beginning of the paper, does not seem to have been adequately realized later on. C.-S. Yih, USA

2211. **Bratt, J. B., Flow patterns in the wake of an oscillating aerofoil,** *Aero. Res. Counc. Lond. Rep. Mem.* 2773, 28 pp., Mar. 1950, published 1953.

Part I Smoke patterns at various spanwise locations in the wake of a rectangular wing performing a rolling oscillation in very slow-speed stream are presented in clear pictures. Experimental techniques for smoke generation and for illumination and photography of smoke patterns are discussed.

Part II Assuming, as an idealization of the wake behind an oscillating airfoil in uniform motion, (a) an infinite two-dimensional vortex sheet with sinusoidal distribution of strength and (b) an infinite row of equal transverse line vortexes of alternate sign (stable), the flow pattern produced by a smoke nozzle moving uniformly relative to the vortex system is computed for each case. Similarity of both calculated smoke traces to experimental trace suggests that assumed distributions of vorticity in wake are possible. Continuous vortex sheet is, however, unstable and must ultimately break up, so (b) seems to be better representation. J. S. Isenberg, USA

2212. **Tomotika, S., and Aoi, T., The steady flow of a viscous fluid past an elliptic cylinder and a flat plate at small Reynolds numbers,** *Quart. J. Mech. appl. Math.* **6,** part 3, 290–311, Sept. 1953.

Noticing errors in several previous papers, authors recalculate the viscous flow past an elliptic cylinder by Oseen's approximation. The drag is also correct to the third order in Reynolds number. As two limiting cases, flows around a flat plate placed parallel to, and perpendicular to the stream are considered in detail. It is interesting that the flow pattern around a flat plate placed edgewise along the free stream is symmetrical at low Reynolds numbers. Y. H. Kuo, USA

2213. **Wallick, G. C., The steady-state flow of gas through glass capillary tubes,** *J. Petr. Technol.* **5,** 11, sect. 1, 20–23; sect. 2, p. 4, Nov. 1953.

Experimental procedures are described for the calibration of seven capillary tubes, with radius r ranging from 0.004 to 0.07 cm, to be employed as comparison standards in nitrogen flow-rate measurements, as a function both of the differential pressure applied Δp and the absolute gas pressure. Records for smaller tubes with $Re \ll 2000$ are in agreement with Poiseuille's law; but for larger ones deviations from that law were observed, not always referable to turbulence. The correction $m\rho Q^2/\pi^2 r^4$ for Δp (where Q is the rate of flow, and ρ the density), as proposed by the author on account of kinetic effects, should compensate the said

deviations with values of the constant m ranging from 1.6 to 2.1.

Owing to a lack of detailed sketch data on the experimental apparatus, a thorough evaluation of energy losses due to extremity conditions is not possible; but reviewer is of the opinion that, for an abrupt entrance contraction and exit expansion, m could hardly attain the above indicated values, even considering a velocity head coefficient as large as 2 for viscous flow.

A. Ghetti, Italy

Compressible Flow, Gas Dynamics

(See also Revs. 2228, 2230, 2237, 2238, 2239, 2241, 2276, 2309, 2310)

2214. Sabol, A. P., Flow properties of strong shock waves in xenon gas as determined for thermal equilibrium conditions, *NACA TN* 3091, 29 pp., Dec. 1953.

The results of calculations are presented for the purpose of showing the effects of ionization and electronic excitation on the flow properties of one-dimensional shock waves in xenon gas. The calculations use statistical mechanics theory with the assumption that thermal equilibrium exists at all points in the flow. The calculations are made by both including and neglecting the effects of electronic excitation, and the results of the calculations are qualitatively compared with available experimental data.

From author's summary

2215. Cabannes, H., Investigation of the waves generated by a body suddenly put in motion in a fluid at rest (in French), *Rech. aéro.* **36,** 7–12, Nov.-Dec. 1953.

Author proposes to solve the problem of a detached shock wave by studying the unsteady motion of bodies and then obtaining the steady flow as a limiting case. The equations of motion are derived for one-dimensional, two-dimensional, and axial symmetrical flow and approximately solved for times close to the initial time. This approximate solution is then used to predict the position of the detached shock wave in steady flow. Agreement of this latter result with experiments on a sphere is not good, but it becomes increasingly better as the speed is increased.

Author states that the theory will have to be pursued further to obtain satisfactory results. P. F. Maeder, USA

2216. Bernstein, H., A double-diaphragm shock tube to produce transient high Mach number flows, *J. aero. Sci.* **20,** 11, 790–791, Nov. 1953.

The theory of the shock tube has been generalized to show that the transient motion produced by combining two shock tubes contains a region of flow at high Mach number. Properties of the flow at the test section are given in terms of the initial pressure ratio. No estimate is made of the probable effect of shock wave attenuation and the deviation of the rarefaction wave from the centered configuration. G. N. Patterson, Canada

2217. Taub, A. H., Curved shocks in pseudo-stationary flows, *Ann. Math.* **58,** 3, 501–527, Nov. 1953.

Method of Thomas [*J. Math. Phys.* **26,** 1, 62–88, 1947] is used to obtain the relationship between the derivatives of the shock curvature at a point and the derivatives of the streamline curvature for a pseudo-stationary flow (a conical flow in which the independent variables are x/t and y/t, where x and y are Cartesian space coordinates, and t the time.)

The results are then used to discuss the reflection of a straight shock from a wall. H. Yoshihara, USA

2218. Sherman, W. L., and Margolis, K., Theoretical calculations of the effects of finite sideslip at supersonic speeds on the span loading and rolling moment for families of thin swept-back tapered wings at an angle of attack, *NACA TN* 3046, 53 pp., Nov. 1953.

Span-load distributions based on theory given in *NACA TN* 2898 [AMR **6,** Rev. 3169] are given for sweptback tapered wings of various aspect ratios over a range of Mach numbers and sideslip angles. All wings have their tip parallel to the axis of wing symmetry, supersonic trailing edges and leading edges subject to (a) both subsonic, (b) one supersonic and the other subsonic, (c) both supersonic. The rolling moment coefficients C_l and the derivative $C_{l\beta}$ (rolling moment due to sideslip) are given for wings (b) and (c).

It is shown that values of $C_{l\beta}$ become less negative in changing from subsonic to supersonic leading edges. A sign reversal in $C_{l\beta}$ takes place for aspect ratio 4 but not for aspect ratio 2 (taper ratio 0.5). Authors suggest that these results can be explained in terms of the changes in leading-edge pressures and the pressure distribution over the entire wing when the leading edge, nearest the Mach cone, changes from a subsonic to a supersonic condition. This effect is always sufficient to cause a reversal in sign for $C_{l\beta}$ but is balanced, to a limited extent, by the infinite pressures acting on the leading tip, which tend to maintain a negative rolling moment. G. M. Lilley, England

2219. Ormerod, A. O., Note on the use of the three-dimensional shock-wave recorder for studying interference in a supersonic wind tunnel, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2798, 9 pp., Dec. 1950, published 1953.

A shadowgraph method of obtaining the positions of tangents to shock-wave patterns is described and applied. A test photograph and diagrams of the flow about a wing planform with 50° sweepback in a 3-in. × 3-in. supersonic wind tunnel are included to illustrate the procedure and the results. The flow fields about a model test may be reproduced in order to determine the shock-wave system or to estimate its interference effects on the model.

The recording apparatus consists of a shadowgraph system which may be rotated ±50° (from its perpendicular position to the tunnel) about the tunnel vertical axis. While the system rotates, a predetermined plane above or below the wing is photographed through a slit on a film moving at a known speed. The film is then analyzed and the wave system about the model computed and drawn.

Due to the wide angular scanning required to reproduce the wave system, long observation windows are necessary and would make this device prohibitive for large supersonic wind tunnels. (Reviewer would like to draw attention to *NACA TN* 2950, "A new shadowgraph technique for the observation of conical flow phenomena in supersonic flow and preliminary results obtained for a triangular wing" by S. Love and G. E. Rigsby, where this problem is considered from an entirely different experimental approach.)

Nevertheless, the author points out the value of this method when employed in a small tunnel as an adjunct to acquire three-dimensional interference information for large supersonic wind tunnels. The present device would also be usefully utilized to study real flow fields about delta wings in order to check the assumptions of linear theory. I. I. Glass, Canada

2220. Bromm, A. F., Jr., and Goodwin, J. M., Investigation at supersonic speeds of the wave drag of seven boattail bodies of revolution designed for minimum wave drag, *NACA TN* 3054, 14 pp., Dec. 1953.

Results are presented from an investigation of the variation

with Reynolds number and Mach number of the wave drag of seven boattail bodies of revolution designed for minimum wave drag according to the theory presented in *NACA TN* 2550.

From authors' summary

2221. **Henry, J. R., One-dimensional, compressible, viscous flow relations applicable to flow in a ducted helicopter blade,** *NACA TN* 3089, 16 pp., Dec. 1953.

The analysis differs from the normal analysis for one-dimensional flow with friction by the addition of a term allowing for the centrifugal pressure gradient along the axis. The resulting equation for a duct of constant area is solved by step-by-step process for a number of specimen cases, and results are presented for the Mach number and pressure distributions along the ducts. Friction and the centrifugal pressure gradients are seen to have opposing effects so that, as the rate of rotation increases, the minimum inlet Mach number for choking also increases. The reviewer notes that the initial equation of motion for a duct of variable cross-sectional area [Eq. 1] is incorrect, but the error should not affect the main body of the analysis and the results which were concerned with a duct of constant cross-section area.

A. D. Young, England

2222. **Miles, J. W., On the transonic drag of a cone cylinder,** *J. aero. Sci.* **20,** 9, 651–652, Sept. 1953.

When applying slender-body approximation to transonic flow in neighborhood of a nonlifting body, the perturbation velocity potential is seen to contain an undetermined function of the streamwise coordinate. In general, it is necessary to consider the outer flow, where approximation is not valid, to determine this function. Author proposes to determine it from an assumed form of the sonic line, in the case of a cone cylinder, where position as well as slope of sonic line is known at shoulder. This is, of course, possible only for that interval of the streamwise coordinate which is traversed when following the sonic line from shoulder to point where slender-body approximation ceases to be valid. Author concludes that at low supersonic Mach numbers with sonic line ending far out on detached shock, the undetermined function contributes to drag only in a small neighborhood of shoulder, and he computes drag using straight-line approximation for sonic line. Result agrees excellently with more accurate calculations of Yoshihara in limit of Mach number one [AMR **7,** Rev. 850].

S. B. Berndt, Sweden

2223. **Nigam, S. D., The rotation of an infinite plane lamina in a viscous compressible fluid,** *Proc. Indian Acad. Sci.* (*A*) **38,** 2, 116–119, Aug. 1953.

The known solution for steady flow due to rotation of an infinite plane lamina in an incompressible fluid is extended to the corresponding problem of compressible viscous fluids. The difficulties due to nonlinearity, viscosity, and heat conduction are partly overcome by neglecting heat transfer and assuming the equation of state $p = p_0 + k\rho^\gamma$, where p_0, k, and γ $(= 5/3)$ are constants. The compressibility effects are confined to the neighborhood of the disk, leaving the general features of the flow the same as in incompressible flow. Continuity requires steady axial flow toward the rotating lamina; the fluid moves radially outward near the lamina.

From author's summary by G. R. Graetzer, USA

2224. **Ray, M., Variation of temperature due to small steady disturbances in a compressible flow,** *Bull. Calcutta math. Soc.* **45,** 2, 45–49, June 1953.

Author considers infinitely small and steady two-dimensional velocity and temperature disturbances within a compressible viscous and conductive fluid, whose pressure, however, is supposed to remain constant, He finds, as a particular solution, proportionality between the velocity and temperature variation, each being expressible by the arbitrary function $f(y + \lambda x)$, where λ depends on the Prandtl number, restricted remarkably as it is, between the limits 3/4 and 1.

A. von Baranoff, France

2225. **Hamaker, F. M., Neice, S. E., and Wong, T. J., The similarity law for hypersonic flow and requirements for dynamic similarity of related bodies in free flight,** *NACA Rep.* 1147, 11 pp., 1953.

Supersedes articles reviewed in AMR **5,** Revs. 482, 2896.

Turbulence, Boundary Layer, etc.

(See also Revs. 2214, 2294, 2295, 2306)

2226. **O'Donnell, R. M., Experimental investigation at a Mach number of 2.41 of average skin-friction coefficients and velocity profiles for laminar and turbulent boundary layers and an assessment of probe effects,** *NACA TN* 3122, 38 pp., Jan. 1954.

An experimental investigation was conducted of laminar and turbulent boundary layers on the outer surface of a hollow cylinder at a Mach number of 2.41 and over a Reynolds number range of 4×10^4 to 6×10^6. For laminar flow, the velocity profile and the skin-friction coefficient are in good agreement with the theory by Chapman and Rubesin [*J. aero. Sci.* **16,** p. 547, 1949], and for turbulent flow with the theory by Rubesin, Maydew, and Varga [*NACA TN* 2305, 1951]. The probe effect seems to be negligible, as long as the ratio of probe height to boundary-layer thickness is not greater than 1/4.

H. Schlichting, Germany

2227. **Siegel, R., and Shapiro, A. H., The effect of heating on boundary-layer transition for liquid flow in a tube,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-178, 12 pp.

Experiments on water flow were carried out in the entry region of a smooth tube. Heating was found to have no significant effect on the position of transition and it generally led to an earlier location of transition. Although the desired effect of delaying transition might be observed with streams of even lower turbulence levels, it may be concluded that in most practical situations it will not be possible to extend the zone of laminar flow by heating of liquid boundary layers.

R. C. Binder, USA

2228. **Tyler, R. D., and Shapiro, A. H., Pressure rise required for separation in interaction between turbulent boundary layer and shock wave,** *J. aero. Sci.* **20,** 12, 858–860, Dec. 1953.

Paper considers immediate neighborhood of separation point and foot of shock induced by separation. Noting that with turbulent boundary layer the pressure rise occurs in very short distance, authors assume that, in region considered, skin friction and mass flow into boundary layer have negligible effects. Thus edge of boundary layer is assumed to be a streamline. Since shock induced by separation is usually weak, flow outside boundary layer is assumed isentropic. Velocity profile upstream of shock wave is represented by power law. Downstream of shock wave, boundary layer is assumed to be on verge of separation. Application of continuity and momentum equations then gives pressure coefficient as function of Reynolds and Mach numbers. Comparison with experiments shows agreement in order of mag-

nitude and in trend with varying Mach number. Trend with varying Reynolds number does not agree with experiments; this discrepancy is attributed to effects of skin friction and mass flow into boundary layer, neglected in theory.

W. A. Mair, England

2229. **Witting, H., On the difference method for the calculation of laminar boundary layers** (in German), *ZAMM* **33,** 8/9, 314–315, Aug./Sept. 1953.

2230. **Cope, W. F., The turbulent boundary layer in compressible flow,** *Aero. Res. Counc. Lond. Rep. Mem.* no. 2840, 8 pp., Nov. 1943, published 1953.

Investigations concern the effect of compressibility on skin friction of high-speed projectiles. The boundary layer is assumed to be turbulent from the nose downstream. Local and mean skin-friction coefficients are calculated for velocity distributions following logarithmic and power laws. It is found, and this is in agreement with results of van Driest and other writers in the United States, that skin friction decreases substantially with increasing Mach number. This effect seems to be almost independent of the shape of the velocity profile.

Author emphasizes the urgent need for experimental verification of these important and favorable effects.

M. A. Dengler, USA

2231. **Attinello, J. S., Boundary-layer control and supercirculation,** *Aero. Engng. Rev.* **12,** 9, 24–30, Sept. 1953.

2232. **Hama, F. R., On the velocity distribution in the laminar sublayer and transition region in turbulent shear flows,** *J. aero. Sci.* **20,** 9, 648–650, Sept. 1953.

Using the relation

$$\tau = \rho l^2(du/dy)^2 + \mu(du/dy) \qquad [*]$$

from mixing length theory and the integral momentum relation between shear stress τ and velocity distribution u, author has calculated mixing length l in laminar sublayer and transition region from experimental velocity distribution in turbulent layer along flat plate. A universal relation

$$l = \alpha^2(1/\nu)(\tau_0/\rho)^{1/2}y^2$$

where α is a numerical constant, is obtained. Substitution of this l in Eq. [*] yields ordinary differential equation for velocity distribution. Solution for u includes linear laminar sublayer profile $u = (\tau_0/\mu)y$ for small y and, with proper choice of α in each case, gives good representation for velocity distribution in viscous region either for boundary layer or for channel or pipe flow.

J. S. Isenberg, USA

2233. **Kramer, M., Turbulence measurements in flight,** *J. aero. Sci.* **20,** 9, 655–656, Sept. 1953.

The ram-pressure oscillations caused by turbulence in the atmosphere generate a high noise level which may be picked up by a microphone carried in flight. For carrier speeds slightly below Mach 1.0, the carrier noise interference may be eliminated by mounting the microphone on the tip of a boom protruding in front of the carrier. The distance between microphone and carrier noise source is then increased by the factor $[1/(1 - M_0)]$ where M_0 is the carrier Mach number. At speeds of approximately one-half sonic speed, the microphone is mounted inside a towed body which must be designed to fly below the turbulent wake of the carrier to eliminate this noise source.

The microphone was installed in a 12-lb towing body 3 ft long, attached to the carrier by a 400-ft cable. The output of the microphone was fed through the cable to an electronic voltmeter. The microphone was tuned to 175 cps with a band width of about 10% center frequency, and the voltmeter was calibrated in decibel center frequency pressure at sea level. It is shown that for a speed of 1000 fps and sea level density, the unit turbulence speed vector can be expressed as a ram-pressure noise level as follows: $\Delta\bar{v}$ = 1 in. per sec = 114 db acoustic pressure (acoustic reference level = 0.0002 dynes per sq cm)

Several series of tests were made in a relatively slow single-engined propeller airplane under fair-weather conditions. The first series demonstrated that carrier noise interference was effectively eliminated. Two flights at 10,000-ft altitude showed that, for a true speed range of 150 to 450 mph, the noise pressure was proportional to flight speed. For a fixed microphone frequency, the variation in noise with speed must be due to eddies of different sizes, from which it is concluded that the average fair-weather turbulence speed vector ($\Delta\bar{v}$) is independent of eddy size.

Four flights at 400-mph true speed ranging from 1000 to 10,000-ft altitude plus two more to extend measurements to 30,000 ft were made to determine the relation between ram-pressure noise and altitude. The effect of wind and sunshine in causing turbulence near the ground was clearly shown, such ground effect disappearing above 10,000-ft altitude. One flight was made under calm hazy conditions in the fall at various altitudes, which indicated that the ram-pressure noise is essentially proportional to the ambient air density, exclusive of the ground effect. The conclusion is tentatively drawn that the average fair-weather turbulence speed vector ($\Delta\bar{v}$) is constant above 10,000-ft altitude, having a computed value of 0.6 in. per sec.

C. E. Carver, Jr., USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 2112, 2215, 2233)

2234. **Rodriguez, A. M., Lagerstrom, P. A., and Graham, E. W., Theorems concerning the drag reduction of wings of fixed plan form,** *J. aero. Sci.* **21,** 1, 1–7, Jan. 1954.

See AMR **7,** Rev. 569.

2235. **Deitchman, S. J., An empirical method for correction of a wing downwash field for the rolling up of the trailing vortex sheet in incompressible flow,** *J. aero. Sci.* **21,** 1, 67–69, Jan. 1954.

2236. **Black, J., and Hunt, R. D., Some measurements of leading edge separation bubbles on a 10-per cent thick symmetrical aerofoil,** *J. roy. aero. Soc.* **57,** 516, 819–823, Dec. 1953.

Pressure distribution and liquid-film tests on a 10% thick airfoil revealed the presence of separation "bubbles" close to the leading edge. These bubbles are formed beneath the boundary layer which separates near the leading edge and re-attaches farther aft; their existence is usually indicated by localized constant-pressure regions in the pressure distributions. It is also believed that if a thin film of liquid (such as a suspension of lampblack in paraffin) is spread on the surface, the scrubbing action of the air rotating in the bubble will tend to draw liquid forward into the bubble, and hence the location and extent of the bubble may be indicated approximately by the accumulation of the fluid.

Many boundary-layer traverses of bubbles on NACA airfoils have been made, but it was felt that similar measurements of the bubbles on this particular airfoil would provide useful data, since the separation characteristics of this section appeared to differ from those in the NACA tests.

From authors' summary

2237. **Johnston, J. F., and Danforth, E. C. B., Some pressure-distribution measurements on a swept wing at transonic speeds by the NACA wing-flow method,** *NACA RM* L7D22, 21 pp., diagrs., photos, June 1947. (Declassified from Restricted, Nov. 10, 1953.)

2238. **Adams, R. E., and Silsby, N. S., Tests of a horizontal-tail model through the transonic speed range by the NACA wing-flow method,** *NACA RM* L7C25a, 24 pp., diagrs., photos, tab., Apr. 1947. (Declassified from Restricted, Nov. 10, 1953.)

2239. **Mathews, C. W., and Thompson, J. R., Free-fall measurements at transonic velocities of the drag of a wing-body configuration consisting of a 45° sweptback wing mounted forward of the maximum diameter on a body of fineness ratio 12,** *NACA RM* L6L26, 18 pp., diagrs., photo, Apr. 1947. (Declassified from Confidential, Nov. 10, 1953).

2240. **Stanitz, J. D., and Sheldrake, L. J., Application of a channel design method to high-solidity cascades and tests of an impulse cascade with 90° turning,** *NACA Rep.* 1116, 20 pp., 1953.

Supersedes article reviewed in AMR **5,** Rev. 3534.

2241. **Eggers, A. J., Jr., Syvertson, C. A., and Kraus, S., A study of inviscid flow about airfoils at high supersonic speeds,** *NACA Rep.* 1123, 27 pp., 1953.

Supersedes articles reviewed in AMR **5,** Rev. 3494; **6,** Rev. 968.

2242. **May, A., and Witt, W. R., Jr., Free-flight determinations of the drag coefficients of spheres,** *J. aero. Sci.* **20,** 9, 635–638, Sept. 1953.

Paper presents sphere-drag measurements from tests in NOL Pressurized Ballistics Range for Mach numbers from 0.8 to 4.7 and for Reynolds numbers from 10^3 to 10^6. These and other data are plotted to show sphere-drag coefficient as function of Mach and Reynolds numbers in that range. H. Luskin, USA

2243. **Landahl, M. T., Analysis of some wing-body-vertical tail interference problems for non-symmetric steady flow using slender-body theory,** *Roy. Inst. Technol. Div. Aero., Stockholm, KTH-Aero. TN* 32, July 1953.

The configuration studied first consists of a body of revolution with symmetrically mounted thin wing and asymmetrical thin vertical tail. Forces and moments due to incidence and sideslip are calculated. The effects of discrete trailing vortexes (as from a wing farther forward) are determined. There is a discussion of afterbody lift. For wings with sweptback trailing edges, the wing-body problem is handled by first transforming to a plane where the body cross section appears as a straight vertical line. This problem leads to an integral equation, which is supposed to be solved numerically.

Author calls attention to another more complete treatment of these problems; viz., A. E. Bryson, AMR **7,** Rev. 891. [See also R. G. Summers, *J. aero. Sci.* **20,** 856–857, 1953, and A. E. Bryson, ibid. **21,** p. 59, 1954.] W. R. Sears, USA

2244. **Zlotnick, M., and Robinson, S. W., Jr., A simplified mathematical model for calculating aerodynamic loading and downwash for wing-fuselage combinations with wings of arbitrary plan form,** *NACA TN* 3057, 38 pp., Jan. 1954.

A method is presented for calculating lift and longitudinal center of pressure on a fuselage in the presence of a wing at subsonic speeds. Wing-fuselage combination is simulated by a system of horseshoe vortexes located on the wing with images located inside fuselage. For midwing configurations with axisymmetric fuselages, the simplified mathematical model can also be used to approximate values of the spanwise lift distribution on the wing and the downwash behind the wing.

H. Lomax, USA

2245. **Muggia, A., Remark on the theory of lifting surfaces** (in Italian), *Atti Accad. Sci. Torino* **87,** 318, 7 pp. 1952–1953.

Short demonstration shows that best choice for location of a lifting-line approximation to replace a lifting-surface vortex distribution governing subsonic flow about a wing planform of arbitrary shape is the quarter-chord line nearly, while boundary condition that requires parallelism of flow vector to zero thickness wing's surface must be applied at $^3/_4$ chord line nearly. Result is well known [see earlier work of J. Weissinger, AMR **1,** Rev. 509, or better, AMR **3,** Rev. 917], but author gives simple and convincing reasons for approximations in rectangular wing case and then, in analogy, uses average value of decadence factors appearing in integral equations in order to arrive at very plausible explanation for the general result.

R. H. Cramer, USA

2246. **Fisher, L. R., Some effects of aspect ratio and tail length on the contribution of a vertical tail to unsteady lateral damping and directional stability of a model oscillating continuously in yaw,** *NACA TN* 3121, 49 pp., Jan. 1954.

This is a comparison of theory and wind-tunnel experiments on the damping in yaw of a vertical tail. Theoretical values are taken from Biot and Boehnlein's analysis of oscillating isolated wings of finite span [*GALCIT Rep.* no. 5, Calif. Inst. Tech., Sept. 1942], which is said to be in agreement with other analyses of the same subject. The theoretical curves exhibit the same phenomenon of negative damping at low reduced frequencies that is familiar in the theory of oscillating two-dimensional wings. The theory also predicts a tail length for minimum damping for each aspect ratio.

The experiments were made by oscillating a simple fuselage carrying a single rectangular vertical surface. The tail length was varied from large positive to moderate negative values, and two aspect ratios (1.5 and 3.0) were tested. The damping in yaw was not measured directly but was computed by means of a formula involving the steady-state lift-curve slope and the phase angle between the displacement in yaw and the (measured) lateral force on the tail surface. The results are not in very good quantitative agreement with the theoretical predictions. There are considerable differences in magnitude, and although the abrupt appearance of instability mentioned above does occur, it occurs at a considerably greater reduced frequency—actually at a frequency in the range of practical aeronautical interest.

W. R. Sears, USA

2247. **Watkins, C. E., and Berman, J. H., Air forces and moments on triangular and related wings with subsonic leading edges oscillating in supersonic potential flow,** *NACA Rep.* 1099, 25 pp., 1952.

Supersedes paper reviewed in AMR **5,** Rev. 481.

2248. **Brewer, G., Calibrating the PBY-6A airplane for meteorological purposes,** *Aero. Engng. Rev.* **13,** 2, 24–28, Feb. 1954.

2249. **Mangler, K. W., and Squire, H. B., The induced velocity field of a rotor,** *Aero. Res. Counc. Lond. Rep. Mem.* 2642, 16 pp., May 1950, published 1953.

Report gives a short account and the results of a theoretical investigation (presented in two previous reports by Mangler)

of the velocity field induced by a lifting rotor. This basic problem has continually plagued the development of rotary wing aircraft. Due to the rather difficult nature of the problem, only limited success and no practical results have ever been achieved in dealing with this problem. Nevertheless, since this problem is basic to a full understanding of rotary wing behavior, continued effort is warranted and attempts such as these are to be commended.

The basic assumption that the induced velocities are small compared to the flight-path velocity presents a serious limitation to the applicability of the results. To define the limits of applicability, the criterion is established that the thrust coefficient (based on flight velocity) be small compared to 1. No indication is given, however, as to the order of smallness required to fulfill this criterion. For present-day helicopters, the value of this coefficient is approximately 1/4 for cruising flight to 1/16 at the maximum speed.

While no quantitative correlation with experimentation has yet been achieved, use of the theory does explain qualitatively certain rotor-blade phenomena. L. Goland, USA

2250. Reed, W. H., III, An analytical study of the effect of airplane wake on the lateral dispersion of aerial sprays, *NACA TN* 3032, 46 pp., Oct. 1953.

The trajectories of spray droplets discharged from an airplane wing were obtained by numerical integrations of the equations of motion, treating the flow field in the vicinity of the wing as a vortex system. Motion and decay of the vortex system and deviations from Stokes law were taken into account.

For ejection of a given spectrum of droplets at a single point on the wing, it was found that the lateral dispersion of spray deposition on the ground increased with altitude and lift coefficient, and when the point of ejection was moved toward the wing tip.

With spray discharged uniformly along the wing the ground deposit was a maximum at the plane of symmetry and rapidly decreased beyond the wing tip. Uniformity and effective width of ground deposition were improved by increasing the spray mass rate with spanwise distance. Decreasing the mean drop size gave better uniformity of deposit for given flight-path spacing.
L. Talbot, USA

Propellers, Fans, Turbines, Pump, etc.

(See also Revs. 2087, 2204, 2221, 2249, 2298, 2305, 2362)

2251. Chilton, E. G., and Handley, L. R., Pulsation absorbers for reciprocating pumps, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-81, 10 pp.

Pulsation absorbers (or surge bottles) are often required in reciprocating-pump installations where pipe vibration, flowmeter errors, and other disadvantages of pulsating flow must be eliminated. Graphs are presented, based on theoretical analyses, for sizing such absorbers for any given installation and desired pulsation amplitude. Experiments with a laboratory unit as well as a few full-scale plant installations confirm the theoretical results. Recommendations are also made for certain important design details. From authors' summary by W. DeLapp, USA

2252. Iversen, H. W., Performance of the periphery pump, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-102, 9 pp.

This pump, sometimes called a friction or tangential pump, acts by exerting viscous forces on fluid and is, therefore, difficult to analyze accurately. Author develops simplified theory leading to expressions for head, power, and efficiency, but these contain coefficients which must be determined at present by test. Basis of analysis is equation of force equilibrium for fluid in flow passage as developed into straight line, both shearing and pressure forces being taken into account, but leakage, bearing losses, and shaft-seal losses being ignored. Characteristic performance curves calculated from theory show good agreement with experiment as far as test data are available. Although this type of pump is not common, largely because its efficiency is low (usually less than 50%), article should be of interest to all persons interested in small pumps. C. W. Smith, USA

2253. Torda, T. P., Hilton, H. H., and Hall, F. C., Analysis of viscous laminar incompressible flow through axial-flow turbomachines with infinitesimal blade spacing, *J. appl. Mech.* 20, 3, 401–406, Sept. 1953.

Paper extends the Lorenz theory of analyzing nonviscous incompressible flow through axial turbomachines with infinitesimal blade spacing to the case of viscous flow. The effect of viscous force is taken into account by modifying the expression of force field. The velocity distribution in each channel is assumed to be a nonsymmetric parabola. Expressions for velocity components, pressure, power input and output for arbitrary blade surface are derived in terms of two arbitrary functions as determined by the blade shape. One of the numerical examples is presented and the flow variables and blade surfaces are plotted.
S.-M. Yen, USA

2254. Thwaites, B., A note on the performance of ducted fans, *Aero. Quart.* **4,** part II, 179–185, Feb. 1953.

This is a continuation of author's previous paper [AMR 5, Rev. 2925]. The strip (blade-element) theory is extended to the calculation of the performance of an axial-flow ducted fan. Based on the assumption that C_D/C_L of the blade section is known at each incidence α and that $C_L = a_0 \sin(\alpha + \alpha_0)$, author shows that the ratio P/Ω^3 (where P is the power and Ω the angular velocity) and the efficiency η of the machine can be considered as functions of Ω/u (u = axial velocity) only. Although these same parameters have been frequently used in practice, author is able to derive relations between them in an elegant manner. A graphical solution of the performance is claimed by author to be only a matter of minutes. An example is included.
H. Yeh, USA

2255. Gruber, J., On the observation of streamlines in radial flow impellers, *Acta Techn. Hung. Budapest* **7,** 1–2, 29–41, 1953.

Smoke introduced at various points into inlet of radial fan and viewed through transparent case with stroboscopic arrangement provided qualitative flow information. Analysis of photographs and direct observation aid understanding about flow separation from blades and regions of most rapid smoke diffusion.
R. G. Folsom, USA

2256. Groth, K., Investigation on oscillations in the pressure ducting of reciprocating compressors (in German), *VDI-Forschungsheft (B)* **19,** 440, 5–22, 1953.

Author examines by means of piezo indicators the oscillation relations in the ducting of a piston compressor. He shows that the resonance frequencies can be obtained very exactly by formulas for simple oscillators composed of tubes and resonators if the container volume is taken into account. Investigated is the effect of standing waves in the pipeline on the indicator diagram, increasing the compression work by 5 to 10%. The possibilities of detuning by pots, orifices, and ramifications are examined and

computed. A summary of well-known and newly developed formulas for the theoretical resonance frequencies completes the paper.
H. Krüger, Germany

2257. **Linnecken, H., On the circumferential efficiency of axial-flow turbomachines** (in German), *Forsch. Geb. Ing.-Wes. B* 19, 4, 97–100, 1953.

2258. **Perlmutter, I., High performance jet engine design dependent upon metallurgical ingenuity,** *J. Metals* **6,** 2, 113–118, Feb. 1954.

2259. **Rogers, W. L., Determination of thrust alignment in rocket engines,** *J. Amer. Rocket Soc.* **23,** 6, 355–359, Nov.-Dec. 1953.

Deviation of the geometric centerline of a rocket nozzle and the effective thrust centerline produced therefrom, termed "gas misalignment," is of concern in solid- and liquid-propellant thrust chamber application. Effects are sufficient to warrant development of measuring equipment as described.

Outlined are (1) possible arrangements for thrust alignment tests, (2) description of ultimately chosen test arrangement, (3) typical test records and their interpretation.

A test program to indicate effect of control of manufacturing tolerance resulted in a deviation of 0.4° misalignment angle for as-cast two-piece nozzle, as compared to 0.05 for 100 μ machined finish. This 0.4° represented an 80-lb lateral thrust from a 12,000-lb-thrust unit, indicating the value of contour machining the nozzle surfaces.
E. S. Starkman, USA

2260. **Laucher, R. G., and Winter, J. S., Optimum exit-nozzle performance for jet engines. A discussion of development experience and design problems associated with several types of variable-area exit nozzles,** *Aero. Engng. Rev.* **12,** 9, 41–45, Sept. 1953.

Of several variable-area nozzle configurations investigated—the clamshell, plug, flap, three-segment, and iris types—the iris-type nozzle exhibited the optimum characteristics. The iris-type nozzle has been found to have a nozzle efficiency comparable to that of fixed nozzles and is, therefore, considered a practical solution to the problem of control of variable exit area for turbojet engines.
From authors' summary

2261. **Ashwood, P. F., and Fletcher, P. J., The performance of some typical turbo-jet engine exhaust systems, with particular reference to the effects of swirl,** *Aero. Res. Counc. Lond. curr. Pap.* 130, 29 pp., Dec. 1951, published 1953.

A description is given of tests made to determine the effect of swirl on the performance of a quarter-scale model of a typical turbojet-engine exhaust system and propelling nozzle. The losses in the system were derived from direct measurement of the thrust.

The nondimensional thrust, expressed in terms of the nozzle area and the total pressure at inlet to the exhaust diffuser, was found to vary linearly with the ratio of ambient to inlet total pressures. At an expansion ratio of 2:1, the thrust with 40° of inlet swirl was only 4/7 of that with zero swirl, but since an increase of swirl angle had the effect of reducing the air mass flow, the thrust per unit of air flow was reduced to 5/7 of the zero swirl value.

Tests made at reduced pressure showed that, to a sufficiently good approximation, the pressure loss factor was a function of $Re^{-0.3}$, where *Re* is the Reynolds number based on the nozzle diameter and nozzle-exit conditions.

An exhaust arrangement suitable for use with reheat, in which the jet pipe diameter was equal to the turbine outside diameter, was found to have a lower over-all loss factor than the standard system for inlet Mach numbers less than 0.6, but at higher velocities it was necessary to use a longer bullet to maintain this superiority.

An annular nozzle was found to give slightly over 2% more thrust at the choking condition than the standard system for the same air mass flow.

The use of thin, cambered struts for supporting the diffuser bullet resulted in increased thrust at large swirl angles.
From authors' summary

2262. **Brosinsky, H., Contribution to the calculation of the charging end state in high-speed diesel engines** (in German), *VDI-Forschungsheft* (B) **19,** 440, 23–39, 1953.

Charging air entering the cylinder of a diesel engine undergoes changes of temperature due to mixture with remaining gas and heat transfer at the cylinder wall. To obtain computation data for this change, author determines a fictitious heat-transfer coefficient by experiments carried out with a one-cylinder diesel engine at different entrance temperatures and different speeds. A comparison with formulas by Nusselt and Jaklitsch shows deviations due to different experimental and computational bases.
H. Krüger, Germany

2263. **Roy, M., Synthesis of self-propulsion by energy method** (English and French), *ONERA NT* 14, 49 pp., 1953.

Author investigates fundamental concepts and definitions associated with propulsion systems, e.g., drag, thrust, and over-all efficiency. Clear and useful definitions depend on difficult problem of defining conditions at infinity when body moves through infinite medium. Author introduces notion of an asymptotic wake.

Part I refers to relatively simple case of nonself-propelled bodies. It gives detailed definition of asymptotic wake, discusses drag and propulsive power, and generalizes d'Alembert's paradox in an analysis of "pure drag in a perfect fluid with asymptotic wake."

Part II refers to the more difficult case of self-propelled bodies. It discusses mechanical actions and thermal exchanges of the intrinsic and extrinsic flows; energy sources; drag and thrust; thermodynamic power and absolute efficiency; actual drag; over-all efficiency; and a jet-propelled body in a perfect external fluid.

Reviewer found some of the author's arguments difficult to follow, and feels that a number of assumptions need further justification.
A. H. Shapiro, USA

2264. **Feldman, A. L., The evaluation of competing rocket power plant components for two-stage long-range vehicles,** *J. Amer. Rocket Soc.* **23,** 5, 297–300, Sept.-Oct. 1953.

The problem of establishing the relative merits of competing rocket power plants for long-range two-stage rocket vehicles is considered. Maintaining missile load and payload weight, the changes in propellant weight, component weight, and specific impulse are related. The relationships derived are applied to an example and the effect on cost is examined.
W. R. Hawthorne, England

2265. **Ehricke, K. A., A comparison of propellants and working fluids for rocket propulsion,** *J. Amer. Rocket Soc.* **23,** 5, 287–296, 300; Sept.-Oct. 1953.

Some significant relations between propellant characteristics (impulse and density), vehicle performance (cut-off velocity and payload), and vehicle design (weight of structure for tanks and feed) are derived and used to study the applicability of various

propellants and atomic working fluids, e.g., hydrazine and oxidizers. For earthbound vehicles, heavier propellants appear preferable. Lighter propellants require too large a tankage and atomic working fluids do not offer enough advantage to pay for the weight of the pile. As the performance of the vehicle is to be increased, high specific impulse becomes gradually more attractive than high density. For cut-off velocities up to 20,000 fps in space, medium gravity propellants such as ozone-methane and oxygen-hydrozene are attractive. Above these velocities the balance between specific impulse and density is in favor of working fluids and nuclear piles. W. R. Hawthorne, England

2266. Pinkel, B., and Karp, I. M., A thermodynamic study of the turbine-propeller engine, *NACA Rep.* 1114, 36 pp., 1953.

Supersedes article reviewed in AMR **5**, Rev. 2705.

Flow and Flight Test Techniques

(See also Revs. 2112, 2211, 2213, 2219, 2233, 2242)

2267. Roebuck, J. R., and Ibser, H. W., A precision multiple-mercury-column manometer, *Rev. sci. Instrum.* **25**, 1, 46–51, Jan. 1954.

The 200-atm mercury manometer described in previous papers is studied experimentally and revised, especially by removing the mercury reservoirs from the measuring system. A rotating loaded piston is used to provide a constant test pressure, and details as to its construction and use are given, as also for the toluene pump, valves, unions, Invar tape, and cathetometers. The temperature control of the manometer and the management of its fluids are described. The barostat piston was known to vary 2 to 3 parts per 10^4 in. cross section. By means of a screw-driven plunger the barostat was held manually at the same vertical position during each of a series of 8 readings of the barostat pressure. The maximum divergence from the mean of the series is 0.83 part per 10^4, and the average of the absolute values of the divergences from the mean is 0.30 part per 10. It is concluded that the manometer can be relied upon to measure a pressure of about 200 atm to within 1 part in 10^4.

From authors' summary

2268. Yngve, V. H., A logarithmic barometer, *Rev. sci. Instrum.* **25**, 1, 43–45, Jan. 1954.

The design of a barometer is described which achieves a logarithmic response over a wide range of pressures by the use of two fluids and a tube of varying cross section. Application of the principle to barometers with other useful nonlinear scales is discussed. From author's summary

2269. Eckenrode, R. T., and Kirshner, H. A., Measurement of pressure transients, *Rev. sci. Instrum.* **25**, 1, 33–40, Jan. 1954.

A general review of fluid-pressure transient measurement and instrumentation is presented. The review is designed to acquaint the reader with the basic problems encountered in transient measurement and to discuss the various types of pressure gages available. The measurement problems include such topics as frequency response, thermal and electrical stability, calibration techniques, and interpretability of results. Some of the more important gage types covered are mechanical, piezoelectric, condenser, strain, inductance, and optical. The discussion of these gages includes a critical evaluation of the important characteristics of each, followed by a table comparing them with each other on the basis of these characteristics. With this background, the choice of a gage best suited for a particular transient-measurement problem should be facilitated.

From authors' summary

2270. Pimlott, J. R., The TMB magnetic micrometer MK II, *David W. Taylor Mod. Basin Rep.* 847, 35 pp., May 1953.

The TMB magnetic micrometer MK II is an electromagnetic instrument by means of which minute mechanical movements may be accurately and remotely measured; thus, the instrument enables the measurement of any force that can be translated into physical movement. The instrument uses a novel linear variable differential transformer, the TMB Magnigage, as the sensing element, and an extremely stable and reliable null indicator to resolve the output of the sensing element into micrometric units. The output of the null indicator may also be fed into an oscillograph for transient investigations.

For the past five years the TMB magnetic micrometer MK II has been in use as the only official torsion meter for full-scale ship performance trials of vessels of the U. S. Navy, U. S. Maritime Administration, and U. S. Coast Guard. This instrument is also in general use at the David W. Taylor Model Basin for the measurement of torque, thrust, and resistance during model testing.

The design and construction of this instrument, as well as application and operating techniques, are presented in this report.

From author's summary

2271. Hopkins, E. G., A stroboscopic flashlamp, *Austral. J. appl. Sci.* **4**, 4, 508–509, Dec. 1953.

2272. Knechtel, E. D., Experimental investigation of two-dimensional tunnel-wall interference at high subsonic speeds, *NACA TN* 3087, 13 pp., Dec. 1953.

Author concludes from closed-throat tunnel tests through the Mach number range 0.3 to 0.9 that, for ratios of airfoil chord to tunnel height up to approximately 0.15, tunnel-wall interference is small and can be accounted for satisfactorily by small-perturbation theory.

Reviewer believes this conclusion should not be accepted without qualification. For example, the NACA 4412 airfoil tested by the author with a chord-to-height ratio of 0.156 results in choking at $M \approx 0.85$, a condition in which it is well known that the theoretical corrections are inapplicable. Even for Mach numbers well below choking, this configuration exhibited appreciable wall-interference effects not satisfactorily corrected by the small-perturbation theory. As an illustration, at $M = 0.75$, $\alpha = 0°$, author's data [fig. 5(b)] show the corrected drag coefficient of the airfoil to be about 35% higher than the drag coefficient of an interference-free airfoil. J. V. Becker, USA

2273. Lukasiewicz, J., Elimination of flow instability in two high-speed wind tunnels by means of high-drag screens, *Nat. aero. Establ. Canad.* LR-83, 26 pp., Nov. 1953.

Pitot-tube boundary-layer traverses and force measurements on half models made in two trans- and supersonic wind tunnels have shown large amplitude flow fluctuations near the working section walls. The flow instabilities were effectively eliminated by installation of high-drag screens (giving a pressure drop of 100 to 200 velocity heads) at the contractions' entries.

From author's summary

2274. Ruptash, J., and Parks, E. K., Wind tunnel balance for half-model tests, *Nat. aero. Establ. Canad.* LR-82, 24 pp., Nov. 1953.

A three-component half-model, strain gage, external-type balance, incorporating a double-pivot system, has been designed for the National Aeronautical Establishment 16- by 30-in. intermittent flow, high-speed wind tunnel. The results of the calibration and preliminary tests have shown that:

(1) The over-all design is satisfactory. (2) The balance output for each component is proportional to the applied load. (3) The maximum interference of drag on lift is about 2.4% of the full lift load (100 lb). (4) The errors due to all the other interactions are within one per cent of the respective full loads. (5) The balance system response time is less than one second and the balance does not require mechanical damping.

From authors' summary

Thermodynamics

(See also Revs. 2259, 2263, 2265, 2266, 2305, 2317, 2332, 2358)

2275. **Stoever, H. J., Essentials of engineering thermodynamics,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1953, vii + 279 pp. $4.50.

This elementary textbook, intended for a one-semester course in engineering classes, is essentially a shortening of the text, "Engineering thermodynamics" by Stoever. The book is divided into three parts: (1) First law of thermodynamics, (2) Second law of thermodynamics, and (3) Applications. The first two parts give a brief introduction to the first two laws of thermodynamics as it is conventionally presented to mechanical-engineering students. The third section consists of: Steam power plants, Internal combustion engines, Refrigeration, Compressors, Nozzles, and Air conditioning.

No attempt at rigor is made, but text has a pleasant style. Numerous examples are given illustrating principles involved, and a good supply of problems (381) are left for the student. It is unfortunate to find such statements as "Heat is defined as something that is transferred between two systems because of a difference in their temperature." Temperature is not defined. The application section is spotty by necessity; the section on nozzles, for example, never mentions the possible existence of shock waves.

Since the text is chiefly for engineers other than mechanical, it is unfortunate to find all the examples from topics primarily of interest to mechanical engineers. This reviewer feels that students, after reading this text, will not fully appreciate the very broad foundations of thermodynamics. It would appear desirous to have a more careful treatment in the first two parts and fewer, but more diverse, topics in the section on applications.

R. A. Gross, USA

2276. **Broer, L. J. F., Note on the efficiency of thermal machines at a finite rate of expansion,** *Appl. sci. Res.* (*A*) **4,** 1–10, 1953.

By the method of characteristics author examines the work done during expansion of an infinite mass of gas at finite speeds. Only weak shocks and simple expansion waves are considered, but it is shown that, providing the speed of the piston is small compared with the speed of sound, the entropy gain corresponds to that derived from simple thermodynamic considerations.

The case of expansion in a finite cylinder, where reflection of expansion and compression waves occur, is briefly investigated in the last section. The conclusion is drawn that, if the number of reflections considered is limited, a deficit in work is obtained, but this loss in efficiency decreases with an increasing number of reflections.

G. C. Quigg, Australia

2277. **Codegone, C., Pressure and entropy of saturated vapors** (in Italian), *Termotecnica,* **12,** 12, 555–557, Dec. 1953.

Author claims that the quantity $(T/p)(dp/dT)$ evaluated along the liquid-vapor saturation curve as well as the entropy of vaporization satisfy approximately the law of corresponding states. The relation proposed for the vapor pressure derivative is exactly equivalent to the vapor pressure equation: $\log p = -(A/T) + B$, which is well known to be at best a rough approximation.

S. Gratch, USA

2278. **Sänger-Bredt, I., Thermodynamics of flue gases of atomic missiles** (in German), *Z. Naturforsch.* **8,** 12, 796–804, Dec. 1953.

In jet propulsion a gas is heated to high enthalpy values and then accelerated to a high rate of flow. The thermodynamic problems related to this acceleration are discussed for extremely high initial enthalpy values. The expansion is assumed to occur isentropically and under conditions of equilibrium. As a final result, the rates of flow for hydrogen are given. It is pointed out that the extremely high rates of flow obtainable for hydrogen (30,000 m/s) cannot be reached for helium.

H. C. Brinkman, Indonesia

2279. **Traustel, S., A generalized "flue gas triangle"** (in German), *Brennstoff-Wärme-Kraft* **5,** 8, 261–264, Aug. 1953.

Oswald's "flue-gas triangle" is a graphical representation of the connection between the CO_2, O_2, and CO content in the flue gas and the "excess air coefficient" of combustion. Originally every combustible required a different graph. The present paper makes the flue-gas triangle universally applicable by means of some auxiliary graphs.

From author's summary by G. Guderley, USA

2280. **Mukherjee, A. K., On the relationship between viscosity and vapour pressure of liquids,** *J. Indian chem. Soc.* **30,** 10, 725–727, Oct. 1953.

A relationship between fluidity and vapor pressure of liquids and temperature has been worked out on the assumption of free volume in liquids, in which the liquid molecules undergo translational motion and the equation verified in 20 liquids, some of which have been shown in the paper.

From author's summary by M. J. Goglia, USA

2281. **Carr, N. L., Viscosities of natural gas components and mixtures,** *Inst. Gas Technol. Res. Bull.* **23,** 60 pp., June 1953.

Report covers the experimental determination of the absolute viscosity of methane and three natural-gas mixtures at pressures up to 10,000 psi and temperatures from 70 to 250 F. The text material covers a literature survey, design of laboratory equipment, techniques, the experimental data and correlations. Data are presented in the form of viscosity-pressure isotherms in order to show the effect of temperature, pressure, and composition on the viscosity of the gases. The information may be used in the analysis of engineering problems involving the flow of gas in pipelines and the flow of gas into or out of underground reservoirs. Important information is included in the document, which is recommended for those interested in this area of engineering.

G. A. Hawkins, USA

2282. **Suciu, S. N., Zoss, L. M., and Sibbitt, W. L., The solubility of nitrogen and hydrogen in water,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-64, 10 pp.

An apparatus was constructed for obtaining phase equilibrium data up to 10,000 psia and 750 F. The solubility of nitrogen in water was measured at 500, 1000, 1500, 2000, and 3000 psia and at temperatures from 32 to 500 F. The solubility of hydrogen in water was measured at 1000, 1500, 2000, and 3000 psia and at temperatures from 32 to 635 F. From authors' summary

2283. Sommerfeld, A., edited by F. Bopp and J. Meixner, Lectures on theoretical physics, Vol. V. Thermodynamics and statistics [Vorlesungen über theoretische Physik, Bd. V. Thermodynamik und Statistik], Wiesbaden, Dieterich'sche Verlagsbuchhandlung, 1952, xiv + 374 pp. DM 23.30.

This is the volume which has been missing to complete Sommerfeld's lectures on theoretical physics. The author was not able to complete this volume. He passed away in 1951 due to an accident. His friends, Bopp and Meixner, completed and edited this volume, a summary of the experiences of the long teaching and research work of Sommerfeld in the fields of thermodynamics and statistics, with interesting additions prepared by the editors.

Thermodynamics is a good example of a well-founded science which did survive, contrary to classical mechanics, the revolution brought about by the quantum theory. New branches were added, however; for example, Nernst's third law of thermodynamics, the application of the second law to the fields of electricity and magnetism, and the thermodynamics of irreversible processes.

The book is subdivided into the following chapters: General thermodynamics, application of thermodynamics to selected special problems, elementary kinetic theory of gases, general statistics, fundamental considerations for an exact kinetic theory of gases. Problems are given for each chapter which were partly prepared by Sommerfeld and partly by the editors. An index with cross references would be much appreciated.

W. M. Conn, USA

2284. Faragó, Gy., Improving the economy of the cooling cycle (in Hungarian), *Magyar Energiagazdaság* **5,** 8, 242–244, Aug. 1952.

The economy of operation in refrigeration plants where cooling is applied at different temperatures can be increased by first cooling the coolant—to be charged into an evaporator at a lower temperature—in an evaporator at a higher temperature. Throttle losses are reduced in this way; vapors arising from the cooling of the coolant are sucked off by a compressor at a higher temperature, the specific power input and the size of which are smaller than the former. Bases of calculations as well as diagrams for economies in power requirements as a function of temperatures are furnished; these are generally valid for all types of coolants. *Courtesy of Hungarian Technical Abstracts* Gy. Faragó

Heat and Mass Transfer

(See also Revs. 2082, 2133, 2224, 2314, 2349)

2285. Garrett, C. G. B., Magnetic cooling, Cambridge, Mass., Harvard Univ. Press; New York, John Wiley & Sons, Inc., 1954, xi + 110 pp. $4.50.

2286. Sidles, P. H., and Danielson, G. C., Thermal diffusivity of metals at high temperatures, *J. appl. Phys.* **25,** 1, 58–66, Jan. 1954.

Thermal diffusivity k (conductivity/density × specific heat) of copper, nickel, and thorium was measured in the temperature range of 0–500 C. Authors employed a dynamic method originated by A. J. Angstrom in 1861. Advantages include unimportance of good thermal contact and surface heat losses; hence, insulation and guard requirements are reduced. The entire specimen is at approximately the same temperature T, permitting determination of $k(T)$. A sinusoidally varying heat source at one end of a long thin rod caused small temperature variations along the rod, which were measured by thermocouples attached at two points and were chart-recorded. In order to eliminate the heat-loss term, some previous investigators have compared wave velocities v or amplitude decrements q for two different periods of variation at the source, which required intervening time for dynamic equilibrium. Authors employed both v and q for a fixed period, thereby simplifying experiment and calculations. Experimental verification of period independence was not reported. Results on Cu and Ni compared favorably with those of others. Results on Th gave approximately constant value for thermal conductivity of 0.409 watt/cm °C from 20 to 400 C, rising to about double this at 500 C. Despite minor errors, mostly typographical, in authors' theoretical development, reviewer believes the experimental method has merit and could well be extended to other applications.

W. C. Shaw, USA

2287. Webber, H. A., Goldstein, D., and Fellinger, R. C., Determination of the thermal conductivity of molten lithium, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-79, 11 pp.

In the present investigation, conductivity coefficients for 99.8% pure lithium were measured over the range 420 to 1002 F. Lithium showed a value of 26 and 18 Btu/hr sq ft deg F/ft at 420 F and 1002 F, respectively. Measurements based on an absolute heat input proved unreliable. The results were based on a temperature gradient measured in an Armco iron heat sink, the thermal conductivity of which appears in the published literature. The estimated error of the results was ±10%.

From authors' summary by Y. S. Touloukian, USA

2288. Fieber, H., The temperature field in a cylindrical wire heated by direct current (in German), *Öst. Ing.-Arch.* **7,** 3, 161–168, 1953.

A cylindrical conductor $O \leq r \leq R$, $-(L/2) \leq z \leq (L/2)$ of finite length L is heated by direct current. As a rule, the heat conductivity of the material is supposed constant, but the electrical conductivity is a linear function of the temperature.

The ends $z = \pm(L/2)$ of the cylinder are kept at prescribed constant temperature T_2, and at the boundary $r = R$ there is radiation into medium at T_1. Also, the initial temperature of the body has a constant value T_0.

The fundamental equation for the temperature T is of the form

$$(\partial T/\partial t) = a\Delta T + bT + C$$

(a, b, C are constants). It should be solved under the above initial and boundary conditions.

Problem in question—although rather difficult—can probably be treated by usual classical methods. Author gives the solution in a very elegant and not generally known way, applying special (Hankel and cosine) integral transformations. A numerical example is included at the end of the article.

In reviewer's opinion, paper shows an interesting method of solving many problems in technical science and mathematical physics. It is recommended to engineers, technicians, and physicists.

V. Vodička, Czechoslovakia

2289. Leppert, G., A stable numerical solution for transient heat flow, *J. Amer. Soc. nav. Engrs.* **65,** 4, 741–752, Nov. 1953.

Greater accuracy is obtained by employing difference equations which are "implicit" rather than "explicit" for the temperatures at the end of a time interval, i.e., the temperatures at the end of the interval for the neighboring points are involved as well as that for the point under consideration. Conversely, larger time intervals can be employed for equal accuracy.

Author shows that it is possible to solve simultaneously for all the temperatures at the end of an interval, and gives the coeffi-

cients for the convenient computation of the 10-space-interval one-dimensional case with $(\Delta x)^2 = \alpha \Delta t$.

Reviewer believes the method would be impractical for two- and three-dimensional problems. C. F. Bonilla, USA

2290. **Sarukhanian, G., The Wanitschew method of elementary balances for the calculation of transient heat fluxes** (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **19,** 4, 101–104, 1953.

Transient temperatures in conducting solids can be calculated only with difficulty by analytical methods, except for simple forms and for constant material properties. Author demonstrates an approximation method in which the changes in average temperature of small but finite volume elements, into which the body is subdivided, are calculated for successive small time intervals by thermal balances within each element. A criterion is given for establishing the maximum size of the time interval. The conductivity and specific heat may vary with temperature, and the latent heat associated with change of state can be allowed for. As an example, the cooling of a cube of magnesite is calculated, allowing for variable properties. The temperature history at the center is compared with those calculated by the heat-conduction equation for various constant values of thermal diffusivity. M. A. Mayers, USA

2291. **Lawson, D. I., and McGuire, J. H., The solution of transient heat-flow problems by analogous electrical networks,** *Instn. mech. Engrs. Proc.* (*A*) **167,** 3, 275–287, 1953.

See AMR **7,** Rev. 934.

2292. **Moyer, J. W., and Riemen, W. A., Heat transfer measurements at sodium-stainless steel interface,** *J. appl. Phys.* 25, 3, 400–402, Mar. 1954.

Experiments to measure the heat-transfer coefficient at a sodium type-347 and stainless-steel interface are described. The temperature range is 100–500 C. It is concluded that wetting does not play a significant role in the heat transfer.

From authors' summary

2293. **Pierre, B., Film coefficient "*h*" for boiling Freon 12 in a horizontal tube** (in Swedish), *Kyltekn. Tidskr.* **12,** 6, 76–81, Dec. 1953.

Paper describes the results obtained with four different copper tubes: 9.5 and 4.78 m with 12-mm ID, and 8.72 and 4.08 m with 18-mm ID. Each tube is placed inside another tube carrying the coolant (water + ethylene glycol) and several thermocouples are arranged along the surfaces. A 50-mm cork insulation surrounds the evaporator.

The study has been carried out for different evaporation temperatures (+10 to −20 C) and heat flux from 800 to 30,000 kcal m^2h, covering both partial and complete evaporation. For the latter the author gives the formula

$$h = 1.95 \cdot 10^{-2} (M_h \Delta i / \pi x_m d^2 L)^{0.80}$$

(M_h is freon quantity kg/h, Δi enthalpy change in evaporator kcal/kg, x_m average vapor quality along the tube length L in m, d diam in m).

The Δt between tube wall and coolant is found from $t = 43.6 \cdot d(\Delta i/L)^{0.4}(q)^{0.2}$ where q is surface area flux in kcal/m^2h.

The expression for partial evaporation is $h = 6.0 \cdot 10^{-3} q \cdot (L/\Delta i)^{0.50}$. Whereas the above data all are related to Freon 12, a few tests were run with Freon 11 resulting in $h = 4.1 \cdot 10^{-3} q \cdot (L/\Delta i)^{0.50}$ for partial evaporation.

In conclusion, the author compares his equations with data from Ashley [*Refrig. Engng.*, 1942], Seigel et al. [*Heat, Piping and Air Cond.*, 1949], Witzig et al. [*Refrig. Engng.*, 1948] and Bryant and Quaint [*Refrig. Engng.*, 1951].

This paper is only a summary of the research work, which will be presented later in its entirety. M. Rand, Canada

2294. **Lighthill, M. G., Theoretical considerations on free convection in tubes,** *Quart. J. Mech. appl. Math.* **6,** 4, 398–439, Dec. 1953.

Analytical solutions are presented for a system composed of a heated vertical tube closed at the lower end and opening into a constant temperature reservoir of cool fluid at the top. The wall temperature is considered constant. Laminar and turbulent flow regimes are considered, each flow for three distinct conditions, depending on whether or not the boundary layer fills the tube or fills it with a stagnant region near the closed end. The analysis was made in virtue of the retention of the buoyant and viscous force terms and the neglect of the inertia terms in the momentum equation, except for the similarity flow case. Under these conditions the laminar flow results are established only for Prandtl number of infinity. The turbulent flow results are given for Prandtl number unity. The results for all cases are presented in terms of Nusselt number and the product of the Grashof number, Prandtl number, and the tube diameter-to-length ratio.

Author indicates the results to be tentative only in virtue of the lack of substantiating experimental data; however, reference to experimental data included in a "Note added in proof" at the end of the paper indicates that the analysis is confirmed, in part at least, for small ranges of the variables in laminar flow.

R. M. Drake, Jr., USA

2295. **Fallis, W. B., Heat transfer in a transitional and turbulent layer at supersonic speeds,** *J. aero. Sci.* **20,** 9, 646–647, Sept. 1953.

Data on recovery factor and Nusselt number are presented for flow over flat plate at $M = 2.5$ in range of Reynolds number (based on wall conditions) between 10^5 and 6×10^5. Reviewer regards transition-region data, like most wind-tunnel transition-region data, as exhibiting to a great extent characteristics of wind-tunnel operating conditions. Reynolds number, in reviewer's opinion, is not high enough to place confidence in results for completely turbulent flow. D. R. Chapman, USA

2296. **Abramowitz, M., On the solution of the differential equation occurring in the problem of heat convection in laminar flow through a tube,** *J. Math. Phys.* **32,** 2/3, 184–187, July-Oct. 1953.

With the assumption of laminar Poiseuille flow, the description of forced heat convection in a circular tube reduces to a linear second-order equation with nonconstant coefficients. The characteristic values of this equation are determined by numerical means. There is no discussion of the physical problem.

W. V. R. Malkus, USA

2297. **Hahnemann, H. W., Nusselt numbers in heat exchangers with laminar flow** (in German), *Forsch. Geb. Ing.-Wes.* (*A*) **19,** 4, 122–123, 1953.

Author gives a survey of the nondimensional heat-transfer coefficients (Nu) for long rectangular channels of heat exchangers with constant or linearly variable wall temperature. The ratio of the sides varies from 0 to 1. The values calculated numerically by the relaxation method, by American authors in particular, are represented in diagrams and tables. A simple correction formula is cited to consider the inlet conditions.

Margot Herbeck, Germany

2298. Burke, E., and Kemeny, G. A., A novel cooling method for gas turbines, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-180, 15 pp.

By spraying water directly onto gas-turbine rotor blades from holes in tubes located in the turbine nozzles, appreciable cooling may be obtained. Several experiments were conducted on a turbosupercharger with various injection arrangements and with both fresh and sea water. Rotor-blade temperatures over 1000 F less than the gas temperature were observed with spray-water rates a few per cent of the gas-flow rate. The cooling mechanism is discussed and some quantitative relations suggested. It is concluded that spray cooling may offer a simpler and more attractive means of cooling gas turbines, thereby permitting the use of higher gas temperatures with more specific output and better efficiency. W. R. Hawthorne, England

2299. Dunkle, R. V., Thermal-radiation tables and applications, *Trans. ASME* **76,** 4, 549–552, May 1954.

Planck's equation for monochromatic emissive power of an ideal radiator is integrated by expanding in a series, and the integral tabulated as a function of the product of the wave length and the absolute temperature. Paper shows that if spectral properties of a surface are known, then the total radiant properties may be computed by numerical integration. Computations are given for the emissivity of anodized aluminum at 1000 R, the reflectivity of white paint for black-body radiation from 1000 R source, and the reflectivity of the same paint for radiation from anodized aluminum at 1000 R. W. A. Wolfe, Canada

2300. Genna, S. J., Nolan, E. J., and Furczyk, A. A., Heat transfer in a gas-fired furnace, *Trans. ASME* **76,** 4, 527–536, May 1954.

An attempt is made to evaluate the separate contributions of direct gas radiation, wall radiation, and convection to a heat sink in a completely enclosed gas-fired furnace. System studied had a very large wall area compared to heat-sink area and contained a nonluminous uniform temperature flame.

Procedure was to determine total flux to sink and also flux to sink from the walls alone by omitting gas and using external heating. The difference was then equal to gas radiation plus convection, and an approximate method for separating these two effects is given. Under the particular conditions studied, about 80% of the heat was transferred by radiation from the walls. Reviewer believes similar studies on this and more complex furnace types would be useful in checking the calculational methods available for predicting heat-transfer rates in enclosures.

E. S. Cohen, Holland

2301. Ghai, M. L., Khanna, M. L., Ahluwalia, J. S., and Suri, S. P., Performance of reflector-type direct solar cooker, *J. sci. indust. Res., India* **12,** 12, 540–551, Dec. 1953.

In this third of four publications, authors give details of experimental testing of a solar cooker developed for manufacture and sale in India. A description of the experimental method includes ingenious devices for measuring solar radiation (to avoid costly equipment). A study is made of the efficiency of the reflector and of relative magnitudes at different temperatures of heat absorbed by the water in the cooking utensil, heat lost to surroundings from hot vessel by convection and radiation, and heat lost by evaporation. Effect of wind, solar intensity, atmospheric turbidity, time of day, and type and size of cooking utensil on performance of 7-sq-ft effective-area reflector is shown in graphs of water temperature against heating time. Results show a tight-fitting utensil cover is needed to reduce evaporation loss. On calm clear days, 1 liter of water boils in 20 to 30 min; on windy days, two to three times longer. A. Whillier, USA

2302. Bonke, K., Estimation of the size of curved smooth surfaces (in German), *ZVDI* **95,** 26, 910–911, Sept. 1953.

Investigations on radiating surfaces require estimations of the real area and not the projected area. Paper describes method of covering the surface with small spheres and weighting the spheres.

A chart gives results for simply curved surfaces.

R. Betchov, USA

2303. Sherwood, T. K., Mass transfer, *Research Lond.* **6,** 11, 423–427, Nov. 1953.

The principal concepts of the rate process of mass exchange between phases as employed in chemical processing equipment are summarized. The market value of various substances produced commercially by purely physical processes increases roughly in proportion to the concentration of the valuable compound in the raw material that has to be processed, owing to the cost of sending the diluents through the purification plants. This seems to be true over a 10^{10} range of initial concentrations extending from natural water to radium. The need for improved processing equipment, particularly for solid-fluid systems, is pointed out and some of the more promising recent equipment developments are reviewed briefly. R. L. Pigford, USA

2304. Jászay, T., The increase of entropy in heat exchangers (in Hungarian), *Magyar Energiagazdaság* **6,** 12, 354–357, 1952.

The most accurate means of examining heat processes and disclosing the existing possibilities for economy is the determination of changes in entropy. By applying this method to uniflow and counterflow heat transfer in heat exchangers, it could be established that changes of entropy were identical in both systems and therefore both systems are equivalent thermically. The only difference between the two systems is in the size of the heating surfaces, consequently in the investment costs. A study of the increase of entropy in respect to changes in mean temperature differences shows that entropy increases with the rise of the differences in temperature. The conclusion to be drawn from the theoretical deduction is that when comparing the thermic properties of various heat exchangers, in addition to drawing a parallel between the increases in entropy, the transfer quantities of heat belonging to the increases in entropy must also be taken into consideration.

Courtesy of Hungarian Technical Abstracts M. Stein

Combustion

(See also Revs. 2278, 2300)

2305. Leiker, M., The gas engine—the internal-combustion engine [Die gasmaschine], Wien, Springer-Verlag, 1953, ix + 260 pp. $11.45.

An excellent combination of theory and application, the book covers both Otto and diesel engines with modified combinations. Theoretical treatment of basic combustion, though not as extensive as that of Jost or Lewis and Von Elbe, is more than adequate for the engineer. Combustion properties of various gaseous fuels such as metbasse, propane, and illuminating gases, are compared under different burning conditions such as gas-air flow and pressure.

The mechanical properties and construction of the various engines are then discussed with the aid of ample diagrams. Operating efficiencies of diesel and Otto engines are compared under various loads. Relatively little is said about automobile engines as known in the United States, but the extensive background material in the construction and operation of benzene and

wood-burning automotive engines should be of value. Diesel engines for marine use and large stationary installations are also described.

Book is a clearly written exposition giving considerable background. It could have been greatly improved by an index, even though the section headings are numerous and descriptive.

J. H. Davidson, USA

2306. **Markstein, G. H., Interaction of a plane flame front with a plane sinusoidal shear wave,** *J. aero. Sci.* **20,** 8, 581–582, Aug. 1953.

Interaction between a combustion wave and an oblique sinusoidal shear wave is treated analogously to the interaction between a plane shock wave and a weak plane disturbance. Amplitudes of the respective shear flows and potential flows are determined from boundary conditions at the flame front. (The density ratio of unburned to burned gas is assumed to be constant, and the burning velocity is introduced as a first-order perturbation, lumping together the influence of transport processes and chemical kinetics.) The results are plotted in the form of amplitudes of the velocity perturbations and flame-front deflection relative to that of the upstream shear flow. Features of the solution are extended to the more complicated case of flame-generated turbulence. The relationship of the wave lengths of the disturbances to a critical wave length where an unstable combustion wave exists is seen to be significant. The authors will publish a fuller account of the work later. J. M. Singer, USA

2307. **Wicke, E., The most important influences on the combustion of solid fuels** (in German), *Zement-Kalk-Gips* **6,** 9, 325–329, Sept. 1953.

Author reports, without experimental data, results of dissertation studies of rates of reactions $C + O_2$ and $C + CO_2$, made on graphite samples. Effects of stream velocity and contact time were separately determined by flowing preheated oxygen (O_2 through heated graphite tubes of varying length in glass apparatus. Carbon monoxide is stated to be primary product of burning in oxygen, but this may be burned to CO_2 by excess oxygen for intermediate contact times. Temperature dependence of both reactions is greater than previously observed, activation energies being 57 kcal/mol for $C + O_2$ and 85 kcal/mol for $C + CO_2$. Experiments in another apparatus lead to conclusion that diffusion within carbon is limited to thin surface layers whose thickness decreases with increasing temperature. Author also discusses factors affecting combustion in practice, including effects of ash constituents on reactivity.

M. A. Mayers, USA

2308. **Roy, M., Structure of shock waves and deflagrations** (in French), *ONERA Publ.* 63, 28 pp., 1953.

A theoretical study, essentially the same as an earlier publication by the same author [AMR **6,** Rev. 193]. A third version of this work, written in English, is to be found in "Fourth symposium on combustion," Williams and Wilkins, Baltimore, 1953, 178–182. R. Friedman, USA

2309. **Travers, S., Waves of shock and combustion** (in French), *Mém. Artill. fr.* **27, 3,** 699–760, 1953.

After recalling a number of classical ideas in relation to shock waves, author comments on papers presented at St. Louis (Haut-Rhin, France) International Colloquium (Oct. 29, 31, 1951) by M. Vernotte on thermokinetics, also by Prof. Shardin on the shock-wave tube, Prof. Burckhardt on the establishment of shock waves, and Prof. Richter on shock waves in elastic isotropic media. This paper deals mainly with developments and commentaries on problems already treated or discussed more or less recently in books and publications. P. Laffitte France

2310. **Travers, S., Waves of shock and combustion** (in French), *Mém. Artill. fr.* **27,** 4, 761–856, 1953.

In this paper the author continues the analyses and commentaries of papers presented at the "Colloque international de St. Louis" (Haut-Rhin, France) (see preceding review). An important chapter deals with the thickness of shock waves and, in connection with Dr. Zoller's communication on the application of the kinetic theory of shock waves, the thickness waves are studied in particular, while theoretical and experimental results already known or published more or less recently are compared. In another chapter dealing with detonations, more or less classical considerations on detonation and shock waves are given in connection with a paper by Dr. Schall on nonideal detonation waves. In a third chapter, on gaseous flames, author summarizes different communications on various problems on diffusion, flow, and explosions in gases (Dr. Oudart, Profs. Brun and Paul, Mr. Darrieus and Prof. Schmidt). Lastly, the author studies deflagrations of solids and liquids (papers of Drs. Roessler, Locuille, Manson, etc.)

P. Laffitte, France

2311. **Potter, J. H., and Dillaway, R. B., Investigation of flame temperatures in a single-cylinder spark-ignition engine,** *Trans. ASME* **75,** 7, 1311–1321, Oct. 1953.

Flame temperatures were experimentally determined in a single-cylinder spark-ignition engine using the electro-optical system proposed originally by Graff. Three fuels were investigated—isooctane, methane, and hydrogen. For calibration, the sodium *D*-line-reversal technique was employed. Individual temperature-crank angle oscillograms were photographed, making it possible to study temperature variations from cycle to cycle and determine maximum and minimum peak cycle temperatures. Statistical methods were applied to the temperature-crank angle and pressure-crank angle oscillograms to obtain average engine levels. The paper serves chiefly to illustrate the utility of the experimental technique. The range of engine operating conditions investigated was quite limited and not typical of modern operating practice. J. H. Childs, USA

2312. **Rosen, P., and Hart, R. W., A constant-area, constant-temperature combustor,** *J. aero. Sci.* **20,** 8, 549–554, Aug. 1953.

A theoretical analysis of a piloted constant-area, constant-temperature combustor with mass addition through the walls is presented. This mass addition consists of a stoichiometric mixture of fuel and air injected perpendicularly through the walls, instantly mixed, and with the flow always regarded as "one-dimensional."

The paper includes (1) an analysis of the conservation equations to determine the behavior of the flow at constant temperature, (2) the role of the combustion efficiency, (3) the kinetics of the reaction based upon an assumed Nth-order reaction equation, and (4) the temperature range for stable operation.

The analysis in many respects is illuminating, but the reviewer believes the article somewhat confusing in several respects. First, an apparent maximum Mach number of $(1/\gamma)^{1/2}$ (choking condition) is derived and compared with the case of a constant-area combustor without mass addition through the walls. However, in the latter case, with friction the conditions of $M = (1/\gamma)^{1/2}$ and $T = \text{const}$ result in infinite heat-transfer rates showing that the constant-temperature condition is physically untenable. A similar result might be expected here with wall friction considered. Second, the assumption of constant tem-

perature as an arbitrary constraint limits the applicability of the problem, since it is a variable which cannot be controlled but which one would like to be able to determine or predict. Finally, the mass flow rate through the wall appears to be an independent variable, although it should normally be a function of the pressure in the combustor at any point. R. E. Bolz, USA

2313. Kämmerer, C., Water injection into the combustion chamber of gas turbines (in German), *Motortech. Z.* **14,** 11, 338–339, Nov. 1953.

Equations are developed for efficiency and power output of a gas-turbine cycle with water injection. The effect of regenerative heating is included. Numerical results are exhibited in a table and a figure, as a function of compression ratio. Efficiency is reduced by the water spray, while power output is increased.

R. Friedman, USA

THE FOLLOWING PAPERS (REVS. 2314–2325 WERE PUBLISHED IN Fourth Symposium (International) on Combustion, 1953; Baltimore, Md., Williams and Wilkins. $7.

2314. Jones, E., Heat transfer in hot wire ignition, 151–157.

Work involved study of fusion energies of wires with terminals, 2.5 cm apart, holding wires for immersion in various media. Procedure consisted of admitting current to wire for a fixed time. Currents were varied until value was reached at which fusion occurred for at least 50% of trials. Reviewer believes method to be accurate.

Author found that total energy necessary to fuse wire was equal to heat resident in wire and adherent film plus rate of heat transferred from wire times time to fuse wire, ($E = E_0 + kt$). For hydrogen, methane, air, and argon there was definite relationship between k and thermal conductivity of gas tested. But for nitrous oxide, which dissociates, greater fusion energies were required than expected from thermal conductivity correlation.

Results agree with earlier work of author and may be explained by reference to known mechanisms of heat transfer. Knowledge obtained is of value in hot-wire ignition systems.

M. Popovich, USA

2315. Hottel, H. C., and May, W. G.; Williams, G. C., and Maddocks, E. E., Jr., Flame stabilization in air-fuel spray mixtures. I. Characteristics of a transverse rod stabilizer. II. The effect of stabilizer dimensions, 715–733.

Data are presented to show the effects of the following variables on the ability of transverse rods to hold flames in ducted streams of air and fuel droplets: Air-fuel ratio, stream velocity, fuel droplet size, fuel volatility, rod temperature, and rod diameter. Blowout velocities are often markedly different and vary somewhat unexpectedly as compared to analogous cases in which fuel is completely gaseous. Observed behavior is qualitatively explained in terms of the collection of droplets by the stabilizer and subsequent feeding of the fuel so collected into the eddy zone. Noteworthy is the observed phenomenon of vapor binding by which the fuel vaporization rate on the rod goes through a maximum with increasing rod temperature. Reviewer believes this paper gives some valuable clues to the performance of baffle-type flameholders in burners using liquid fuels.

J. B. Fenn, USA

2316. Williams, G. C., and Shipman, C. W., Some properties of rod-stabilized flames of homogeneous gas mixtures, 733–742.

By measurement of pressure distributions, chemical analysis of gases in the wake, and schlieren photography, propane-air flames held on cylindrical rods have been studied in ducted burners. Divergence of flow streamlines near the rod is increased by the flame. This results in increased convergence near the wall. It is shown that molecular diffusion can affect the composition of the eddy zone. The effect is slight with large rods and high velocities. Approach to blowout conditions always seems to be accompanied by a marked increase in density inhomogeneity in the flame zone. Unfortunately, these interesting observations do not yet clarify the detailed mechanism of flameholding by baffles. The authors are well aware that much remains to be done. J. B. Fenn, USA

2317. Grove, J. R., and Walsh, A. D., The propagation of cool flames, 429–439.

Propagation of cool flames of diethyl ether through a heated pyrex tube was studied; such studies may lead to clearer understanding of normal hot flames. For a 50-50 mixture with oxygen, slow oxidation began at 140 C and a minimum pressure limit (P_1) of 20 mm Hg and spontaneous cool flames appeared at 180 C and 7 mm. At constant temperature, P_1 for propagation of ignited mixtures occurred at about 45% ether and varied from 50 mm at 25 C to about 7 mm at 175 C. Isotherms of oxygen pressure P_O against ether pressure P_E approach an asymptote P_E' at big P_O and are of a linear form $P_O = (P_O)_0 + KP_E$) for big P_E. Added inert gases raise P_1 for a given temperature in the order of effect, $H_2 > He > CO_2 > N_2 > A$. Propagation rate is decreased in the order of effect, $H_2 > He > CO_2 > N_2$. Authors formulate critical condition for cool flame propagation: [(Constant net chain-branching factor for early stages of spontaneous reaction at critical temperature in presence of temperature gradients)—(heat losses to walls and cold gas)]/[total heat capacity of the volume element] = critical const. A peroxidation reaction mechanism which would explain the results is presented.

G. L. Dugger, USA

2318. Price, T. W., and Potter, J. H., Factors affecting flame velocity in stoichiometric carbon monoxide oxygen mixtures, 363–369.

This paper deals with the determination of the effect of small amounts of hydrogen on the flame velocity in stoichiometric carbon monoxide-oxygen mixtures which were saturated with water vapor at room temperature. The flame velocities are determined by the use of a spherical, transparent, constant pressure bomb centrally ignited.

The authors conclude that, over the range of stoichiometric CO-H_2-O_2 mixtures studied, (1) for mixtures with constant moisture content, the flame velocity rises nearly linearly with the increase of molecular hydrogen; (2) there is some evidence that the rate of increase of the flame velocity is greater if hydrogen is added as molecular hydrogen; (3) it is felt that a satisfactory bomb and technique have been developed which overcome the principal objections of the soap-bubble method.

The authors hope that the flame velocity and composition data reported may be of some use in the study of the kinetics of the chemical reactions involved. R. Delbourgo, France

2319. Laffitte, P., and Delbourgo, R., Ignition by condenser sparks. Regions of flammability of ethane, propane, n-butane and n-pentane, 114–120.

An extended survey of ignition and upward propagation of flames in hydrocarbon-oxygen-nitrogen mixtures. "Limits of flammability" (for ignition by single spark) and generally wider "limits of propagability" (for ignition by multiple sparks) are determined, along with limiting pressures.

Results for different atmospheres (O_2 and 4–9N_2) with propane and butane indicate two different regions of propagability, sometimes overlapping. In second region, of richer mixtures, flames often did not extend throughout tube. Second region is not distinguishable with pentane.

Results emphasize relative ease of ignition by successive as contrasted to single sparks and the absence of any absolute flammability region. R. C. Anderson, USA

2320. **Egerton, A. C., Everett, A. J., and Moore, N. P. W., Sintered metals as flame traps,** 689–695.

Disks of sintered bronze, sintered stainless steel, and of solid bronze, with various numbers of 0.015-in. holes, were tested for stopping flames of stoichiometric hydrogen-oxygen and methane-oxygen mixtures in a 1.74-in. diam brass tube. Trap efficiency was measured in terms of "limiting safe pressure" (LSP), the minimum initial mixture pressure (same on each side of trap) for flame passage. Best trap tested, sintered bronze of 0.01575-in. statistical particle size, 0.433 porosity and 0.14 in. thick, showed LSP of 31-cm mercury; disk of same particle size and 0.235-in. thickness had LSP of 49-cm mercury for $2H_2 + O_2$. Other bronze disks gave similar LSP's and higher resistance to flow. Sintered stainless steel that gave 34-cm LSP, produced 23 times the pressure drop. Drilled bronze disks having similar LSP values showed over 10 times the flow resistance of sintered disks. Comparing hydrogen-oxygen and methane-oxygen mixtures, ratio of LSP's for a given disk was approximately inversely proportional to enthalpies of oxidation of the mixtures. Use of two disks back-to-back almost always reduced flame-trap efficiency, probably due to build-up between rough disk surfaces of gas at high pressure, which ignites violently and aids flame passage. Lack of specimens with sufficient range of physical properties has prevented detailed study of their effects on flame-trap efficiency. W. P. Jensen, USA

2321. **Fenn, J. B., and Calcote, H. F., Activation energies in high temperature combustion,** 231–239.

Temperature dependence of burning speeds depends on that of rate of reaction, determined by energy of activation. Authors attempt to evaluate these from burning-velocity measurements in two different ways. From effect of initial temperature on burning velocity, activation energies have been calculated on the basis of both Tanford-Pease diffusion theory and Zeldovich-Frank-Kamenetzky-Semenow thermal theory. Results, though satisfactory, give certain range only of activation energies. Second method uses approximate relation between lean limit flame temperature and activation energy. Anomalous behavior of CS_2 is attributed to slow diffusion (hydrogen atoms not available).

Reviewer believes that only average activation energies with observed degree of indeterminacy can be expected.

W. Jost, Germany

2322. **Dixon-Lewis, G., Temperature distribution in flame reaction zones,** 263–267.

The degree of refraction of a light beam initially parallel to a stationary flame front is proportional to the gradient of the refractive index. Author utilizes this principle to deduce temperature distribution in flames of premixed gases from measurement of light refraction. The flames under study (a 9.7% CH_4-air flame at 1 atm and a 66.7% H_2-air flame at 0.4 atm) were burned above a rectangular orifice. The sides of the flame corresponding to the longer sides of the rectangle were nearly planar; hence the deviation of a series of light beams 0.1 mm wide and initially parallel to one of these sides was observed. The zone of rapid temperature change was found to be about 1 mm thick for each of the flames studied. The accuracy of the method would appear to be restricted by the limited degree of flatness which can be obtained in a flame and by end effects; however, author corrects for the latter by using two rectangular burners of different lengths. He does not consider the temperature profile obtained for the H_2-air flame to be of sufficient accuracy to justify calculation of the heat-release pattern therefrom. However, reviewer believes the method to be capable of somewhat greater refinement.

R. Friedman, USA

2323. **Fristrom, R. M., Prescott, R., Neumann, R. K., and Avery, W. H., Temperature profiles in propane-air flame fronts,** 267–274.

The curving streamlines through a flame front inclined to the direction of the approach flow (i.e., a Bunsen flame) are measured by adding MgO particles of a few microns diameter to the gas mixture. A diametral plane across the circular burner is illuminated, and photographs are taken. Since the pressure variation through the flame is negligible, the temperature distribution may be deduced from these streamlines by means of the perfect gas law and the continuity equation. A correction must be applied for the change of the average molecular weight of the gas due to reaction. Several arguments are adduced to show that the measured particle tracks correspond precisely to the gas streamlines. The reviewer remains unconvinced.

The results, for near-stoichiometric propane-air flames at 1 atm, show a rise to a maximum temperature 200–400 C above the final equilibrium temperature. Also, peculiar kinks appear in the temperature curves near the beginning of the luminous zone. If any of this "fine structure" is real, it is extremely important to the understanding of flame propagation. However, refractometric studies of Dixon-Lewis and Burgoyne and Weinberg, and thermocouple studies of Friedman (all presented at this symposium) do not show any such features. Unfortunately, these various workers have not studied exactly the same flames. Further experiments appear to be needed to establish the validity of these results. R. Friedman, USA

2324. **Fabri, J., Siestrunck, R., and Fouré, C., On the aerodynamic field of stabilized flames,** 443–450.

A method for finding the flame boundary of a homogeneous combustible gas, established in the wake of a stabilizer located on the axis of a constant section duct, is developed. Stationary combustion wave is regarded as a line of discontinuity of thermodynamical and aerodynamical values, so that combustion is represented by a discontinuity of total enthalpy of flow. The flame front is assumed to be nearly parallel to the flow, streamlines of which deviate very little from an axial direction. The equation expressing the variation of velocity at any vertical distance from the axis in terms of enthalpy and entropy is established, which leads to formulas convenient for calculating (1) flow velocity of combustion products, (2) choking velocity, (3) axial velocity distribution, and (4) geometrical shape of flame front. The methods are illustrated with some examples. Reviewer believes this paper will contribute to the design of combustion chambers of jet engines. I. Sawai, Japan

2325. **Barr, J., Diffusion flames,** 765–771.

The appearance and stability of flames issuing from a cylindrical burner into a cylindrical tube coaxial with the burner are examined. The fuel, butane, is supplied through the burner, and air is admitted through the annular space between the burner and the outer tube. Fuel and air flow rates are varied over a wide range. Ten types of stable flames, corresponding to ten

regions on a log (fuel flow) vs. log (air flow) plot, and the manner of flame extinction along the border of these regions, are described and illustrated in detail. The flame length may show periodic time variations (fundamental frequency: 3–20 cps) over a range of fuel flow rate, this range depending on apparatus geometry. These variations were studied with a movie camera. It was observed that under certain conditions, during part of the cycle, a gap appears which severs the flame into two parts and which is propagated toward the flame tip. Graphs of flame length vs. time are presented which qualitatively describe this phenomenon. Investigations by the author and by others into the factors controlling fluctuation frequency and flame stability are briefly mentioned. A. W. Gessner, USA

Acoustics

(See also Revs. 2168, 2184)

2326. Richardson, E. G., edited by, Technical aspects of sound, vol. I, Amsterdam, Houston, New York, London, Elsevier Publishing Co., 1953, xviii + 544 pp.

Book is the first of two volumes and covers acoustic materials, acoustics of buildings, noise, speech and hearing, sound reproduction, analysis and synthesis of sound. A second volume is to be devoted to ultrasonics.

Since a number of authors have contributed to the work, the level and point of view vary appreciably. The sections on acoustic material and acoustics of buildings develop their subject and serve as an introductory treatment of the field, while the section on hearing tends to an enumeration of experiments and types of apparatus, without much development or integration.

Reviewer believes that the book is one in which someone with a scientific or technical training can obtain a considerable general knowledge of technical acoustics. It is not an elementary book, nor is it a specialist's treatise; it does supply a great number of references (more than 700) for study.

The English translation of the articles by foreign writers is occasionally poor. R. T. Beyer, USA

2327. Lawley, L. E., The absorption of sound in carbon dioxide contained in narrow tubes, *Proc. phys. Soc. Lond.* (*B*) **67,** 409, part 1, 65–69, Jan. 1954.

Measurements of the ultrasonic absorption in carbon dioxide at frequencies between 40 and 120 kcps have been made, utilizing a technique in which the gas is contained in a narrow tube of the order of 1-mm diam. The results so obtained are in agreement with previous measurements. In reviewer's opinion, the major interest of this article consists in the extension of the techniques previously described [Lawley, L. E., title source, **65,** p. 181, 1952] to the case of nonclassical gases.

M. S. Weinstein, USA

2328. Hikata, A., Ultrasonic attenuation in polycrystalline steel, *Bull. Gov. mech. Lab., Tokyo* no. 1, 7 pp., 1954.

Paper shows how the attenuation of ultrasonic waves in steels changes when the specimens are magnetized or stressed.

From author's summary

2329. Bezuszka, S. J., Scattering of underwater plane ultrasonic waves by liquid cylindrical obstacles, *J. acoust. Soc. Amer.* **24,** 6, 1090–1095, Nov. 1953.

Tamarkin [title source, **21,** p. 612, 1949] has presented experimental results on sound scattering by liquid cylindrical obstacles having a diameter of the order of ten wave lengths; he also gives a series solution for the resulting sound field based on the assumption that the incident wave is plane. Author has used this solution to compute the pressure distributions corresponding to the conditions of Tamarkin's experiments. Good qualitative agreement between computed and experimental results was confirmed; quantitative discrepancies seem to be due largely to the plane-wave assumption. M. C. Junger, USA

2330. Graham, G. M., The measurement of the velocity of sound in liquids, *J. acoust. Soc. Amer.* **24,** 6, 1124–1127, Nov. 1953.

A laboratory method is presented for precisely measuring the velocity of sound in liquids at frequencies as low as 0.3 mc. The sound field is set up between two parallel baffles, one containing the projector, the other the receiver. As the baffles are moved apart (effectively moving the field with the transducers), successive maxima are found at half-wave-length distances. Measurements in water show no dispersion between 0.6 and 7.6 mc within the limits of error ($\pm 0.2\%$). Reviewer believes that similar results could be obtained with pulsed systems, but the necessary equipment would be more complex and expensive.

E. Ackerman, USA

2331. Rozenberg, L. D., Two-mirror concentrator of ultrasonic waves, Nat. sci. Found. tr-146, Dec. 1953; *Dokladi Akad. Nauk SSSR* (*N.S.*) **91,** 5, 1091–1094, Aug. 1953.

In order to obtain ultrasonic waves of very high intensity in liquid media, author proposes the following design, which is similar to A. Barone's [AMR **6,** Rev. 1397]: Reflect plane waves emitted by circular source, first by outside surface of paraboloid of revolution, then by inside surface of larger ellipsoid of revolution with one of its foci coinciding with focus of paraboloid, so that pencil of ultrasonic waves will converge upon second focus of ellipsoid at large aperture angle. Author's mathematical analysis shows that the amplification coefficients K_p and K_v of pressure and of velocity are proportional jointly to the radius R of the emitter, the wave number k of the sound waves, and a factor depending on the eccentricity e of the ellipsoid and the ratio $(2c/R)$, where $2c$ is distance between foci. The factors K_p/kR and K_v/kR are plotted as functions of e for several values of $2c/R$; for small e and large $2c/R$ they approach their maximum values, ln 2 and $(1 - \ln 2)$. R. Heller, USA

2332. Parthasarathy, S., Mahendroo, P. P., and Mathur, S. S., Ultrasonic absorption coefficient in liquids by the thermal method, *J. sci. indust. Res., India* **12,** 10, 457–458, Oct. 1953.

Ultrasonic absorption coefficients have been measured in six liquids using the new thermal method developed in the National Physics Laboratory of India. The results are in good agreement with the values obtained by other methods.

From authors' summary

2333. Mikhaĭlov, I. G., Absorption of ultrasonic waves in certain viscous liquids, Nat. sci. Found. tr-59, July 1953; *Dokladi Akad. Nauk SSSR* (*N.S.*) **89,** 6, 991–993, Apr. 1953.

Reports measurements of sound attenuation at from 3 to 7 mcps in cottonseed oil, tung oil, and castor oil. Author concludes that in cottonseed oil the attenuation is "classical" (Stokes), and states the same is true for linseed and sunflower-seed oils. Tung and castor oils show relaxation of shear viscosity with relaxation times of 1.2 and 2.2×10^{-1} sec, respectively. No references to the considerable United States literature on theory of configurational relaxation are given.

M. Greenspan, USA

2334. **Keller, G., Ultrasonic testing of mass products in water immersion,** *Acta Techn. Hung. Budapest* **7,** 3–4, 359–386, 1953.

The Belgian "Ultrasonel" apparatus is automatic equipment for testing of mass products shaped like solids of revolution. The tested cylinders rotate under water and are displaced simultaneously in the axial direction, the ultrasonic beam transmitting the piece radially. The flaw diagram is recorded by a fast-acting vibrational writing mechanism, a converted magnetic pickup. The power of revolution depends, among other factors, on the dimensions of the flaws, the initial diameter of the beam, the traversing speed of the flaw across the beam, the data of the signal voltage connector relay, and the surface finish conditions. These factors are discussed in detail. The wave length in the material is 5.2 mm. O. Ruediger, Germany

2335. **Miles, J. W., On radiation and scattering from small cylinders,** *J. acoust. Soc. Amer.* **24,** 6, 1087–1089, Nov. 1953.

Analysis suggested by theory of supersonic flow past slender bodies is applied to scattering of transient disturbances by cylinders of small cross section, and to radiation from cylinders of varying cross section. G. N. Ward, England

2336. **Nomoto, O., Molecular sound velocity and molecular compressibility of liquid mixtures,** *J. phys. Soc. Japan* **8,** 4, 553–560, July-Aug. 1953.

Soil Mechanics, Seepage

(See also Revs. 2132, 2152)

2337. **Croney, D., and Coleman, J. D., Soil structure in relation to soil suction (pF),** *J. Soil Sci.* **5,** 1, 75–84, Jan. 1954.

Measurements of the suction and volume of soils as a function of moisture content and degree of disturbance are described. The work was carried out at the Road Research Laboratory as part of an investigation into the distribution of moisture in road and airfield foundations.

A classification of soils based on the shrinkage characteristics is used to present the results. Incompressible soils are exemplified by chalk and sand, fully compressible soils by a typical heavy clay, and partially compressible soils by a silty clay. It is shown that a range of moisture contents can be in equilibrium with a given suction and that this fact can be interpreted in terms of soil structure.

For compressible and partially compressible soils, it appears that a unique relationship between suction and moisture content exists for each soil in the fully disturbed condition represented by the Atterberg limit tests. From authors' summary

2338. **Lundgren, H., and Mortensen, K., Determination by the theory of plasticity of the bearing capacity of continuous footings on sand,** *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. I, 409–412.

Constructing the rupture lines by the method used in the theory of plasticity, the theoretically exact bearing capacity of continuous footings on a horizontal sand surface for several cases is obtained. The well-known formula due to Terzaghi is criticized by results which show a discrepancy amounting to about 30% in the case of a rough base. T. Mogami, Japan

2339. **Greathead, W. R., Some aspects of subsoil drainage in relation to paving design,** *Trans. S. African Instn. civ. Engrs.* **3,** 8, 221–227, Aug. 1953.

Author sets out the criteria for filter material and refers briefly to the physical characteristics of permeability and capillarity. A recommended type of design for the subsoil drainage of roads and aerodrome pavings is described and other uses of filter material are mentioned. Examples of good and bad practice in subsoil drainage are given. From author's summary

2340. **Mayer, A., and L'Herminier, R., The bearing capacity of piles in cohesive soils,** *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. II, 60–65.

Authors point out that during the process of driving a pile into the ground the state of plastic equilibrium is reached in two limited regions: (a) an annualr space around the pile all over its length, and (b) a bulk-like space around and under its lower end.

In an earlier paper, L'Herminier, starting from this experimental observation, derived a formula to evaluate the point resistance of a deep continuous footing (two-dimensional problem) in the case of a cohesionless and weightless medium. In this formula the point resistance was a function of the geometric characteristics and the roughness of the foundation, the angle of internal friction of the soil, the tangential and normal stresses acting on the lateral surface of the foundation. The values of these stresses were set equal to those acting in the state of passive earth pressure. In order to solve the same problem, but in the three-dimensional case, an empirical coefficient was introduced. In the present paper, a cohesive soil is considered. Authors make the same previous assumptions and apply the theorem of the corresponding states (Caquot). They derive also a formula for the skin friction. These formulas have been applied to interpret the results of a pile-loading test and two sounding tests. The value of the angle of internal friction ϕ_s, calculated by this way, appears to be related to the angle ϕ measured with laboratory tests by the ratio $\operatorname{tg} \phi_s = 2/3 \operatorname{tg} \phi$. It seems that an analogous relationship takes place between c_s and c.

The reviewer remarks that the value assumed for the resultant stress on the lateral surface of the foundation has a character of arbitrarity that only extensive experimental evidence might justify. Better information on the physical properties of soils and on testing procedures adopted in measuring the shearing resistance would have greatly increased the value of the paper.
A. Croce, Italy

2341. **Brandes, G., Behavior of pile foundation while excited by vibration** (in German), *Bautech.-Arch.* no. 9, 20–44, 1953.

For the economic design of foundations for reciprocating machines or machines having unbalanced rotating masses, it is necessary to know the dynamic characteristics of the foundation. The dynamic characteristics of interest are the natural frequency of the foundation loaded by the machine and the damping of this vibrating system. The natural frequency depends, of course, also on the properties of the soil carrying the foundation and the type of foundation. For this particular case, the foundation consists of a heavy slab of reinforced concrete resting on piles driven into the soil either in a vertical or in a slanted direction.

These foundations do not have an infinite stiffness, and hence the danger of exciting resonant frequency vibration exists under the presence of dynamic forces. The resonant frequencies obtained for a few practical cases are in the order of 5 to 30 cps. The magnification factor was measured to be between 2 and 15. Most of the damping is contributed by the soil. The wide spread in the magnification factor is due to the variation in soil participation for the various modes of vibration. The high value refers to vibration in the horizontal direction, the low value to vibration in vertical direction.

Calculation of the resonant frequency from static load tests did not give satisfactory results. Comparison of so-calculated

values and those obtained from vibration tests showed a considerable discrepancy. An explanation is the difference in the embedding of the piles in the soil under loads of short and long duration. R. O. Fehr, USA

2342. Lorenz, Bearing capacity of rigid sheet piling and mast foundations (in German), *Bautech.-Arch.* no. 8, 79–82, 1952.

Author shows a method for calculating bearing capacity of rigid bulkheads and foundations of masts, taking into account that earth resistance is dependent on magnitude of displacement. This enables him to calculate the necessary depth of penetration for an admissible angle of rotation of the rigid bulkhead or the mast foundation, once the relations between type of soil, density, displacement, and earth resistance are known. These are the object of current experiments. E. Rathgeb, Argentina

Geophysics, Meteorology, Oceanography

(See also Rev. 2248)

2343. Goody, R. M., The physics of the stratosphere, New York, Cambridge Univ. Press, 1954, x + 187 pp. $5.

Author gives a lucid description and analysis of properties of the earth's atmosphere between the tropopause and the base of the ionosphere (from about 6.5 to 80 km above the earth's surface.) A brief history of discovery of the stratosphere and a discussion of upper atmosphere nomenclature is followed by listing and description of balloon, aircraft, and rocket methods of probing the atmosphere, together with deductive means of stratospheric study such as sound propagation, behavior of meteorites, and scattering from searchlight beams. Techniques for measurement and estimation of upper-air temperature accompany graphical and tabular presentation of temperature data. Special methods for studying amount and distribution of water vapor, carbon dioxide, ozone, and rare gases are given. The frost point hygrometer used for study of stratospheric water vapor is described in some detail. The "umkehr" or "reversing" effect of ozone is especially well presented.

Some particularly fine work has been done recently by the British on clear-air turbulence and upper-air winds. Goody reviews this material all too briefly and discusses as well the stratospheric field of motion shown on mean maps and vertical cross sections.

Goody's concluding chapter deals with the radiation balance in the stratosphere. This is a field in which he has done much original and outstanding work. Formal mathematics, held to a minimum elsewhere in the book, appears here, but the chapter may be read with great understanding even without too much attention to the mathematics. The section on molecular absorption is excellent.

Goody throughout gives some notion of both the space and time changes in the properties or processes discussed, thus avoiding a static approach often found in studies of physics of the atmosphere.

For a book with a 1954 imprint and a dust-jacket claim of describing ". . . the present state of knowledge, making use of the latest available information" it is unfortunately about 4 years out of date. The stratospheric temperatures from rockets are much better presented in Newell's "High altitude rocket research" [Academic Press, N. Y., 1953]. There is no reference to any of many excellent articles on the stratosphere in the "Compendium of meteorology" [Amer. Meteor. Soc., Boston, 1951] where recent developments in ozone study and radiation equilibrium are presented. His discussion of upper-air research methods includes no mention of the "sky hook" balloon capable of carrying up to 600-lb payload ["Physics and medicine of the upper atmosphere," Univ. of New Mex. Press, 1952], nor of Whipple's recent paper on meteors as sources of upper-air information ["Advances in geophysics," vol. 1, Academic Press, 1952].

Present work contains a magnificent array of over 60 excellent diagrams and 17 tables. References number over 200.

R. C. Staley, USA

2344. Chow, V. T., Frequency analysis of hydrologic data with special application to rainfall intensities, *Univ. Ill. Engng. Exp. Sta. Bull.* no. 414, 80 pp., 1953.

This is a study of statistical theory concerning the analysis of extremes. Attention is devoted to maxima and "exceedances" of hydrologic data. Exceedance is defined as the top class interval when a given series of observations is arranged in descending order of magnitude. The primary object of the analysis is to determine the recurrence interval of a given magnitude. The theory governing this recurrence interval is discussed and formulas are derived.

It is shown that the maximum values have a frequency distribution function which is different from the distribution function of the original set of data. The same is true for the series of exceedances and its distribution function.

The theory of curve fitting is reviewed and also the use of confidence limits. An example of the application of the analysis is illustrated with rainfall data for Chicago for the period 1913–1947. The availability of hydrologic data in Illinois is discussed and sources are listed.

The analysis method discussed could be applied in statistical prediction of rainfall extremes at a given station.

H. Riehl, USA

2345. Bigg, E. K., The formation of atmospheric ice crystals by the freezing of droplets, *Quart. J. roy. meteor. Soc.* **79,** 342, 510–519, Oct. 1953.

Using the results of laboratory experiments on the supercooling of purified water, the freezing of cloud and raindrops is examined. It is shown that at temperatures lower than about −30 C in cold-box or expansion-chamber experiments, the drops freeze in approximately the numbers that would be expected if they were pure water. Those that freeze at temperatures higher than about −20 C seem to be more numerous than would be the case if the drops were pure. An interpretation of the main features of the Findeisen and Schulz expansion-chamber experiments is found to be possible without appealing to the action of foreign ice-forming nuclei, although there is a discrepancy between calculation and experiment at temperatures higher than about −20 C. In the atmosphere, formation of cirrus clouds is shown to become possible at temperatures below about −35 C, glaciation in stratiform clouds to become appreciable at temperatures below about −20 C, and freezing of raindrops in strongly convective clouds to become important below about −13 C, without the presence of ice nuclei. It is concluded that freezing nuclei may be important at temperatures above about −20 C, while their presence at lower temperatures will be masked by the freezing of uncontaminated drops. From author's summary

2346. Battan, L. J., Observations on the formation and spread of precipitation in convective clouds, *J. Meteor.* **10,** 5, 311–324, Oct. 1953.

2347. Amble, O., A smoothing technique for pressure maps, *Bull. Amer. meteor. Soc.* **34,** 7, 293–297, Sept. 1953.

A technique is proposed to replace mean pressures computed by averaging over time through introduction of a "damped barometer." Introduction of an artificial lag in pressure curves will

smooth out the irregular short-period fluctuations which one usually desires to eliminate with time means, and retain only longer-term, more slowly varying features. Considering sinusoidal pressure waves, author shows, for properly chosen relations between the artificial lag and the large scale features desired to bring out, that the damped barometer possesses characteristics to be preferred over time averages. He also shows a practical way to compute damped barometer charts from the normally available undamped observations.

This technique may provide a real advance and should be considered seriously by all doing work with long-range trends in meteorology. H. Riehl, USA

2348. **Petterssen, S., On the relation between vorticity, deformation and divergence and the configuration of the pressure field,** *Tellus* **5,** 3, 231–237, Aug. 1953.

In the work on numerical prediction of pressure and flow patterns in the atmosphere, the prognostic equation used is generally based on the assumption that the vorticity of the actual wind can be replaced by that of the geostrophic wind where $C_g = (1/f)\nabla^2 Z$; C_g is the relative vorticity using the geostrophic assumption, f is the Coriolis parameter, and $\nabla^2 Z$ is the Laplacian of the geopotential of an isobaric surface.

Paper analyzes the reasons for the success of this assumption in numerical prediction, shows where it will break down, and advocates the use of a somewhat different approximation to the actual vorticity in the prediction equation, namely, a quantity $P = 2\nabla^2 Z + f^2$. The author arrives at this conclusion by derivation from the inviscid hydrodynamic equations of a deformation theorem. Deformation theorem shows that, in divergenceless flow, a certain portion of the absolute vorticity, namely P, is conserved as well as the total absolute vorticity. Thus neglect of the deformation terms, although affecting the value of the vorticity itself, is of no consequence in the prediction equation. Author extends his analysis to divergent flow and shows that P is there also a more satisfactory prediction quantity. A comparison is made in actual cases between use of C_g and use of P as prediction quantities. Results shows that geostrophic approximation will become significantly poor in storms of appreciable intensity where both the vorticity and deformation are large. Paper provides considerable insight into the validity and meaning of the approximations used in numerical forecasting, but more physical elucidation of the results would have been highly desirable. Joanne Starr Malkus, USA

2349. **Surinov, Yu. A., Radiative transfer in an absorbing and scattering atmosphere** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk.* no. 10, 1455–1471, 1952.

Author's previous paper [AMR **6,** Rev. 2960] is concluded and supplemented by considering the various types of problems arising in the theory of radiative transfer and the methods appropriate to their solution. In addition, the specification of radiative equilibrium is discussed and an equation is given which covers the general case of heat transmission involving radiation, conduction, and convection. R. Eisenschitz, England

2350. **Donn, W. L,, and Blaik, M., A study and evaluation of the tripartite seismic method of locating hurricanes,** *Bull. seism. Soc. Amer.* **43,** 4, 311–329, Oct. 1953.

Tripartite records from the U. S. Navy stations at Bermuda, Cherry Point, and Miami were studied in detail for the 1950 hurricane season. Following a discussion of the theoretical error expected in this study, the results of single and average azimuth computation are given. Since the error between computed and observed storm azimuths exceeds the theoretical by a considerable amount, a study of the causes of the errors was undertaken. The difficulties are considered to result from instrumentations and procedure, lack of wave coherence at the three elements of the tripartite net, and refraction or multiple wave paths.

A large range in velocities was observed, with indications that the lower values are the more reliable. Selection on a velocity basis gives somewhat better success than averaging all readings over the chosen interval of time. Suggestions for improvement of the instrumentation program are given.

From authors' summary

2351. **Friedman, D. G., The height variation of lateral gustiness and its effect on lateral diffusion,** *J. Meteor.* **10,** 5, 372–379, Oct. 1953.

Data derived from a unique observational arrangement at Round Hill Field Station, Mass., allow the investigation of the instantaneous vertical variation of wind-direction fluctuations in the lowest 44 m of the atmosphere. Three observational runs under different thermal conditions have been analyzed. An estimate, from these data, of the vertical distribution of lateral diffusion is given in terms of the variation of Sutton's lateral virtual diffusion coefficient with height. The computed values of this coefficient are found to be somewhat larger than those given by Sutton. From author's summary by F. J. Plantema, Holland

2352. **Fofonoff, N. P., A theoretical example of wind-induced circulation in a semicircular canal,** *Trans. Amer. geophys. Un.* **34,** 5, 725–727, Oct. 1953.

The steady-state stream function for the vertical circulation produced by a uniform horizontal wind stress on the surface of a canal of semicircular cross section is derived analytically. The streamlines have been calculated and a comparison is made with some experimental results obtained by Hidaka and Koizumi in 1950 using a thin elastic-plate model.

From author's summary

2353. **Dronkers, J. J., Tidal calculations used to plan the enclosure of the Braakman** (in Dutch), *Ingenieur* **65,** 32, B.155–B.162, Aug. 1953.

The design and the system of closing the last gap based on the results of the tidal calculations insured that the currents in this gap were as small as possible during the closing. For practical purposes, the main points of interest are the maximum current velocities and the current velocities round the slack water at high tide and at low tide. The paper also compares the process of closing a shallow and relatively wide gap to the closing of a deep and relatively narrow gap. From author's summary

2354. **Faure, M., Calculation of energy losses in a tidal estuary (Gironde). Theory and execution of calculations by means of an electronic calculator** (in French), *Houille blanche* **8,** B, 747–759, Nov. 1953.

2355. **Heaps, H. S., Stresses in the earth's crust under an axial symmetrical load,** *Trans. Amer. geophys. Un.* **34,** 5, 769–775, Oct. 1953.

Explicit formulas are obtained for the stresses produced in a thick plate by an arbitrary surface loading symmetrical about some vertical axis when the lower surface of the plate is supported in such a manner that, at any place, its vertical displacement is proportional to the vertical stress acting across it. By suitable choice of the constant of proportionality, the formulas may be applied equally well to a consideration of a thick slab supported by an elastic foundation and to the problem of the crust of the

earth subject to isostatic compensation. The formulas are applied to estimate the stresses in the lower portion of the earth's crust during loading by an ice cap. From author's summary

2356. Howes, E. T., Tejada-Flores, L. H., and Randolph, L., Seismic model study, *J. acoust. Soc. Amer.* **25,** 5, 915–921, Sept. 1953.

A rectangular prismatic limestone slab, with a cut at 45° with one of its surfaces to represent a geological fault, was immersed in a round corrugated-iron water tank. Acoustic waves were generated in the tank by underwater electric discharges. The output of a pressure-sensitive receiver was photographically recorded and the oscillograms were analyzed to study the geometrical aspects of wave propagation, reflection, refraction, and diffraction. Several traverses were made, investigating the effects of slippage along the fault plane and of separation of the two halves of the model. Authors propose to continue this study as an aid in interpreting complex seismic records.

G. Sved, Australia

Lubrication; Bearings; Wear

2357. Eschmann-Hasbargen-Weigand, The application of roller and ball bearings [Die Wälzlagerpraxis], München, R. Oldenbourg, 1953, xii + 372 pp., 396 figs.

Compiled by the engineering staff of Kugelfischer Georg Schäfer and Company, a major German manufacturer of ball and roller bearings, the book is intended to supply the machine designer with all the background and data he needs to select the proper bearings for any specific purpose and to design the bearing installation according to best modern practice. The various types of rolling bearings are described, and the international standards for dimensions, tolerances, and fits are given. The theoretical basis for calculation of carrying capacity and life is set forth in the conventional manner. Further chapters are devoted to the design of complete bearing installations, including methods of assembly and lubrication and the causes of various types of failures. Calculations and drawings of a number of representative bearing installations used in marine, automotive, tool machine, and general engineering illustrate modern practice.

A. G. Cattaneo, USA

2358. Englisch, C., Wear, performance characteristics, and economy of internal-combustion engines [Verschleiss, Betriebszahlen und Wirtschaftlichkeit von Verbrennungskraftmaschinen], Wien, Springer-Verlag, 1952, x + 288 pp. $12.40.

This book is one of a series on internal-combustion engines edited by Professor List of Graz. The major portion of the volume is devoted to a discussion of wear phenomena. A collection of data regarding wear of various parts of the engines is presented and influence of material, surface finish, operating conditions, and lubrication is discussed. In the second section, author deals with engine characteristics, including the description of experimental setups for performance determination and complete performance charts for a variety of engines, most of them of European manufacture. The last section contains a brief discussion of economic aspects that should be considered in the selection of specific engine types. The book was first written in 1943 and, while it has been revised in 1952, the presented material still reflects the conditions of war under which it was written, especially as far as reference to recent foreign studies is concerned. A. Fejer, USA

2359. Osterle, F., Charnes, A., and Saibel, E., On the solution of the Reynolds equation for slider-bearing lubrication—VII. The nonsteady-state operation of tilting-pad slider bearings, *Trans. ASME* **76,** 2, 327–329, Feb. 1954.

Authors consider load-carrying capacity and coefficients of friction of a pivoted pad bearing which is subjected to sinusoidal vibration in the direction normal to the bearing surface. The deduced relationships as functions of amplitude and frequency of the oscillation would indicate improved load-carrying capacity over the steady-state pad. In the discussion, H. Blok points out that oscillatory motion is detrimental to hydrodynamic lubrication and that analytical treatment ought to take into account the same critical film thickness for oscillating and steady pad. At sufficiently high frequencies, oscillatory motion possibly might be beneficial, depending on the magnitude of the inertia effects induced on oil flow. R. Schnurmann, England

2360. Charnes, A., Osterle, F., and Saibel, E., On the solution of the Reynolds equation for slider-bearing lubrication—VIII: The optimum slider profile for viscosity a function of the pressure, ASME Ann. Meet., New York, Dec. 1953. Pap. 53–A-38, 3 pp.

Authors consider the problem of finding the optimum profile for a film-lubricated slider with no side leakage, considering the effect of viscosity change with increasing pressure. They conclude that this profile is exactly the same as the stepped profile obtained by Rayleigh, assuming constant viscosity.

W. O. Richmond, Canada

2361. Edler, E., Statical bearing capacity of lubrication oil (in Swedish), *Tekn. Tidskr.* **83,** 44, 945–947, Dec. 1953.

For lubrication of sleeve bearings, it is pertinent to know the load capacity of very thin oil films at very low speeds between axle and bearing.

Paper mentions how the static load capacity of a very thin oil film (with no velocity) between two flat and parallel glass plates may be tested. The distance between the plates is measured by different pressures on the plates and by different oils, and curves for the relations between plate pressure and oil-film thickness are given. It is suggested that these testing methods may give information about oils when they are used for lubrication in bearings. A. R. Holm, Denmark

2362. Taddei, M., New experimental methods studied at the "Istituto Nazionale dei Motori" (in Italian), *Ric. sci.* **23,** 12, 2139–2151, Dec. 1953.

Report describes activities developed at the Istituto in the field of devices and methods of measurements. Among those procedures reported are methods for observing performance of spark plugs, impureness of exhaust gases, cetane and octane numbers above 100, checking of piezoelements for rapid motors, measurement of stresses and temperatures of rotating parts, and measurement of temperature of self-ignition of fuel oil.

Finally, new researches on wear, refrigeration of turbine blades, and properties of lubricating oils are presented.

From author's summary by A. Balloffet, Argentina

2363. Filz, C. J., Wax lubricant improves sawing of aluminum alloy sheet stock, *Amer. Mach.* **97,** 20, p. 153, Sept. 1953.

2364. Tourret, R., Foaming and aeration of oils in aviation powerplant, *J. roy. aero. Soc.* **58,** 517, 53–60, Jan. 1954.

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